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MILITARY CONSTRUCTION SUPERVISION AND ADMINISTRATION COST FOREC--ETC(U)
MAY 77 M J O'CONNOR, B THOMPSON

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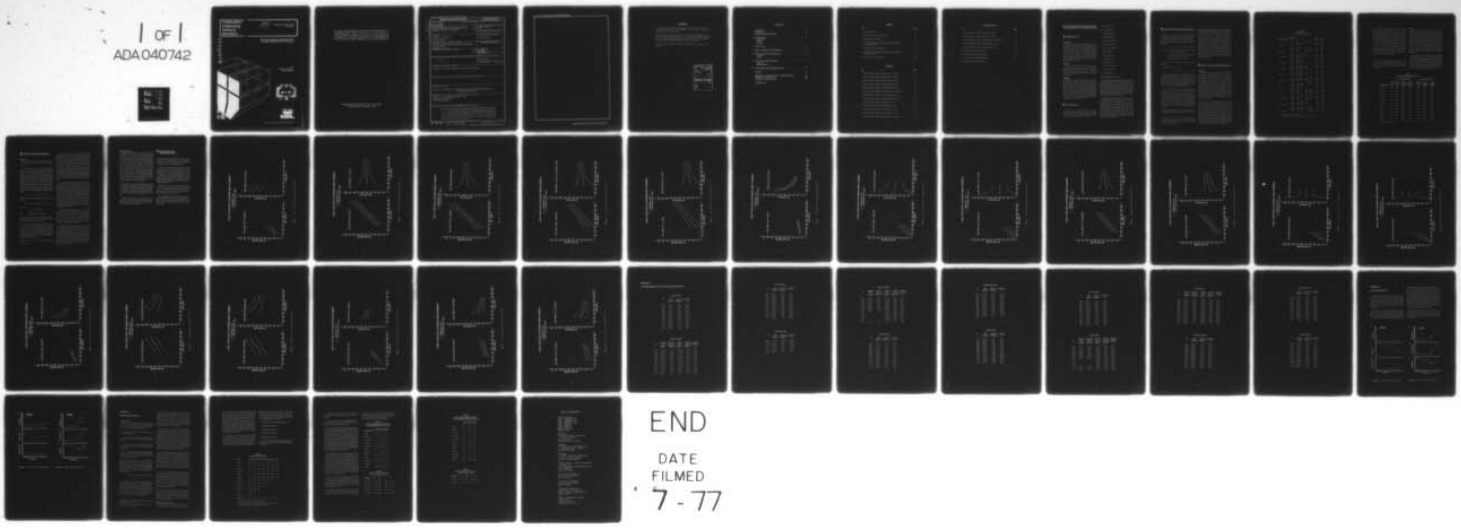

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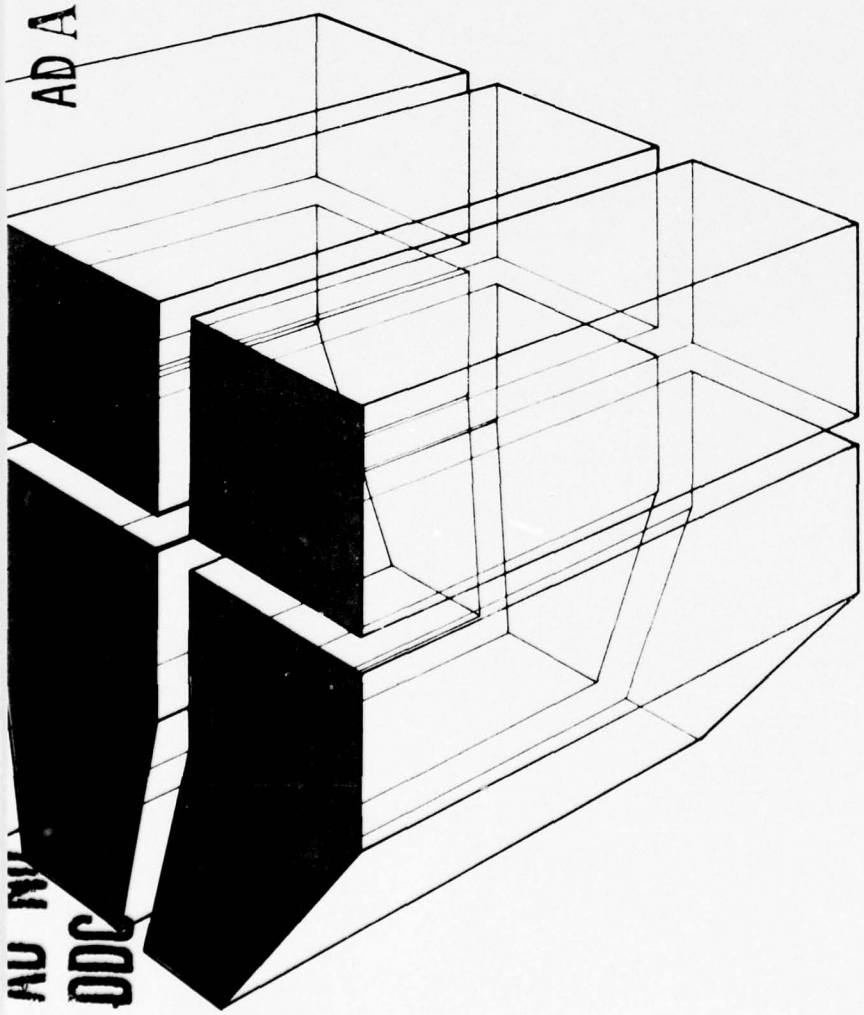
May 1977

MILITARY CONSTRUCTION SUPERVISION AND ADMINISTRATION COST FORECASTS



by
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Bruce Thompson

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20. ABSTRACT (Continue on reverse side if necessary and identify by block number)

This report presents a statistical model for forecasting supervision and administration (S&A) costs to aid the Directorate of Military Construction, Office of the Chief of Engineers, in establishing yearly limits for Corps of Engineers Division/District S&A rates. Data for 12 military construction Divisions/Districts from fiscal year 1963 (FY63) through FY76 were analyzed. A statistically significant model for 10 Districts was developed and verified using a retrospective test. S&A costs/rates for FY77 and FY78 were predicted as a function of the estimated work placement.

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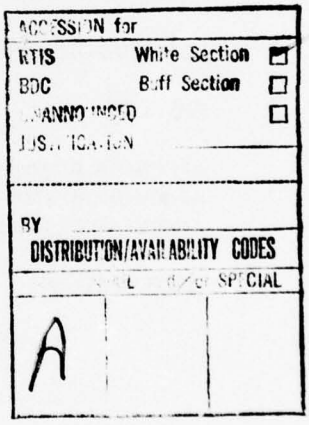
FOREWORD

This research was conducted for the Directorate of Military Construction, Office of the Chief of Engineers (OCE), under IAO MCC-C-76-2 dated 3 March 1976. The OCE Technical Monitor was Mr. D. A. Spivey.

The work was performed by the Management Systems Branch (FAM), Facility Acquisition and Construction Division (FA), U. S. Army Construction Engineering Research Laboratory (CERL), Champaign, IL. The Principal Investigator was Mr. M. J. O'Connor. Dr. O. E. Rood, Jr. is Chief of FAM and Mr. E. A. Lotz is Chief of FA.

COL J. E. Hays is Commander and Director of CERL and Dr. L. R. Shaffer is Technical Director.



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MILITARY CONSTRUCTION SUPERVISION AND ADMINISTRATIVE COST FORECASTS

1 INTRODUCTION

Background

Every year, the Directorate of Military Construction (DMC), Office of the Chief of Engineers (OCE), establishes annual limits for each Corps of Engineers Division/District's supervision and administration (S&A) costs for military construction. These limits, which are expressed as a percent of the dollar value of the estimated work placement (EWP), are currently established using an empirical procedure based on the Division/District's performance in the previous 4 to 5 years and the EWP for the next fiscal year.

Objective

The objective of this work was to develop a statistical model for forecasting S&A costs to aid DMC in establishing S&A limits for each military construction Division and District. The model was to be formulated so that easily obtainable data could be used to forecast future S&A costs.

Approach

Available data on the variables thought to affect S&A costs were reviewed. A model was formulated based on these variables, and regression analysis was used to fit the model to the data. The predictive capability of the model as a function of the number of years of data used in its development was investigated. The fit of the model was checked, and its capability to accurately forecast S&A rates was determined using a retrospective test. The model was then used to predict S&A costs and rates of 11 military construction Division/Districts for FY77 and FY78.

2 DATA REVIEW

S&A costs for FY63 through FY76 were collected from the "OCE Program Review and Analysis: Division and District Performance Data" report for the following 14 military construction Division/Districts:

a. Alaska District

b. Baltimore District

c. Fort Worth District

d. Huntsville Division

e. Kansas City District

f. Los Angeles District

g. Mediterranean Division

h. Mobile District

i. New York District

j. Norfolk District

k. Omaha District

l. Pacific Ocean Division

m. Sacramento District

n. Savannah District

Appendix A presents the raw data.

The Huntsville Division was eliminated from consideration because insufficient data were available. The Mediterranean Division was also eliminated because the recent Saudi Arabian Government workload has invalidated the historical data. Sufficient data for analysis were available for the remaining 12 Division/Districts, although some adjustments were required. The New York District data were adjusted to include the offshore work done from FY66 through FY71.

The Baltimore and Norfolk Districts were consolidated during the period FY71 through FY73, and the total workload was reported by Baltimore. Similarly, the Omaha and Kansas City Districts were consolidated during the period FY71 through FY75, and the total workload was reported by Omaha. For the purpose of data analysis, the data for each of these pairs of Districts was adjusted to reflect the proportion of the total work that would have been placed by each District had the consolidation not taken place. Appendix B presents these adjustments.

3 MODEL FORMULATION AND ANALYSIS

Based on the initial data review and the detailed formulation procedure described in *Military Construction Engineering and Design Cost Forecasts*,[1] the relationship between S&A costs for a particular Division/District, estimated work placement, and time was postulated as:

$$S_i = b_{0i} + b_{1i}W_i + b_{2i}T + b_{3i}W_iT \qquad \text{[Eq 1]}$$

where S_i = predicted S&A costs for the i^{th} Division/District (millions of dollars)

W_i = estimated work placement for the i^{th} Division/District (millions of dollars)

T = time period (FY63 = 0, FY64 = 1 . . .)

b_{0i}, b_{1i}, b_{2i}, b_{3i} = coefficients for the i^{th} Division/District.

The S&A rate (P_i) is defined as:

$$P_i = 100 \times S_i/W \qquad \text{[Eq 2]}$$

Because of the limited amount of data available for individual Divisions/Districts, the possibility of combining data from some or all of the Districts based on similar S&A cost performance was investigated. It was found that the prediction limits did not improve significantly as a result of this pooling (Appendix C). Therefore, none of the Division/Districts were pooled.

Due to the increasing level of work placement in recent years, the earlier data may not reflect the current performance of the Divisions/Districts. A test was made to determine the effect of deleting earlier data and using only a fixed number of the most recent years' data. It was found that using 12 years of data provided significantly better predictions than 13 years, while using less than 12 years of data did not significantly improve the predictions. (Appendix C details this analysis.) Hence, 12 years of data were used for model development.

When regressed against FY65 through FY76 data, the postulated model provided a good fit for 11 of the Division/Districts, explaining 72.8 to 98.2 percent of the variance of the data (Table 1). The model did not fit the data for the New York District; it explained only 37.0 percent of the variation within the original data due to the concentration of all the work placement for New York within a very narrow dollar range. The large standard errors for the Omaha District and Pacific Ocean Division caused their prediction limits to be very wide. Omaha District's large standard error is partially explained by the large increase in work placement for FY76. In the case of Pacific Ocean Division, however, the large standard error is an inherent part of the process. As Table 1 shows, the model for Pacific Ocean Division is changing every year. Due to this erratic behavior, the Pacific Ocean Division was eliminated from further consideration.

4 MODEL VERIFICATION AND RESULTS

Verification

The validity of a forecasting model is determined by its capability to predict future performance. A systematic approach to verifying the model is to conduct a retrospective test. Since the current year's data may not be available when the next year's S&A limits must be established, the model may be required to predict performance 2 years in the future. The model's capability to predict both 1 and 2 years ahead was therefore tested. The retrospective test was conducted by comparing the actual FY76 S&A costs to the FY76 costs predicted by the model developed from FY63 through FY74 data (a 2-year-ahead prediction), and to the FY76 costs predicted by the model developed from FY64 through FY75 data (a 1-year-ahead prediction). Table 2 presents the results.

In three cases, the actual S&A costs were not contained within the 95 percent prediction limits. Two of these cases were the 2-year-ahead predictions for Baltimore and New York Districts. In both of these cases, the 1-year-ahead predictions did contain the actual S&A cost within the 95 percent prediction limits. In the third case, Omaha District's actual S&A cost for the 1-year-ahead prediction was below the lower prediction limit. This is probably due to the large increase (89.8 percent) in work placement for Omaha District in FY76. It appears that Omaha District was suddenly tasked with more work than it had capabilities to handle, resulting in the low value for actual S&A cost.

[1] M. J. O'Connor, G. J. Brown, and J. R. DeCardy, *Military Construction Engineering and Design Cost Forecasts*, Technical Report P-77/ADA035262 (U. S. Army Construction Engineering Laboratory [CERL], 1976).

Table 1
Regression Results
$S = b_0 + b_1 W + b_2 T + b_3 WT$

Division District	Fiscal Year Data	b_0	b_1	b_2	b_3	S* (million $)	R^{2**}
	63-74	1.789		.148	.00562	.161	.706
	64-75	.592	.0475			.184	.664
Alaska	65-76	.647	.0456			.178	.765
	63-74	.499	.0354			.268	.945
	64-75	1.584		−.139	.00375	.247	.982
Baltimore	65-76	1.450		−.114	.00372	.273	.982
	63-74	1.112	.0369	−.119		.306	.909
	64-75	1.132	.0372	−.125		.304	.938
Fort Worth	65-76	1.179	.0388	−.146		.297	.952
	63-74	1.033	.0138			.074	.815
	64-75	1.051	.0130			.077	.801
Kansas City	65-76	1.112	.0113			.075	.794
	63-74	1.201	.0375	−.089		.192	.942
	64-75	1.118	.0391	−.080		.205	.926
Los Angeles	65-76	1.123	.0387	−.074		.222	.915
	63-74	0.514	.0508		−.00156	.203	.978
	64-75	1.051	.0442	−.101		.233	.972
Mobile	65-76	1.221	.0432	−.117		.239	.971
	63-74	.270	.0579		−.00192	.161	.761
	64-75	1.341	.0222	−.039		.184	.442
New York	65-76	1.931		−.140	.00360	.183	.370
	63-74	.132	.0600		−.00187	.109	.864
	64-75	.407	.0342			.137	.746
Norfolk	65-76	.691	.0217			.131	.835
	63-74	1.539		−.047	.00362	.225	.947
	64-75	1.644		−.103	.00450	.329	.950
Omaha	65-76	1.059		.109	.00230	.446	.950
	63-74	2.157	.0349	−.419	.00676	.514	.936
	64-75	.129	.0716	−.056		.595	.897
Pacific Ocean	65-76	4.994		−.736	.01076	.561	.914
	63-74	.487	.0484	−.049		.125	.877
	64-75	.361	.0514	−.043		.129	.902
Sacramento	65-76	.519	.0367			.119	.961
	63-74	.154	.0506	.128	−.00417	.163	.903
	64-75	.608	.0426		−.00187	.183	.807
Savannah	65-76	.826	.0374		−.00169	.172	.728

*S = Standard error of the estimate.

**R^2 = Percent of variance of original data explained by the model.

A measure of the precision of the prediction for Omaha District can be obtained from Table 2 by taking the percent absolute deviation between the actual and predicted S&A cost. This gives a 40.2 percent deviation for Omaha District. This measure can be applied to all the Districts in Table 2. The results, which are presented in Table C2 under the column for 12 years of data, give an average absolute deviation of 13.54 percent between actual and predicted S&A costs, with a range of 0.3 to 40.2 percent. This implies that there was, on the average, a 13.54 percent difference between the S&A costs predicted by the model and the actual S&A costs for FY76. It is important to note that because no adjustments were made to the model predictions, this is a worst-case situation.

This verification demonstrates two important concepts: (1) the 2-year-ahead predictions should be updated by the 1-year-ahead predictions if possible, and (2) the user must be aware of the applicable range of the model.

Results

Figures 1 through 11 show the FY 77 and FY78 prediction equations and graphs for the 10 districts for which the model provided a good fit, as well as New York District (for reference only). The prediction limits indicate the accuracy of the prediction. The following example indicates how they are interpreted. For Baltimore District (Figure 2a), if the estimator assumes an estimated work placement of $90 million in FY77, he/she can be 95 percent confident that the actual S&A cost will be between **$3.80** million and **$5.27** million. Equivalently, he/she can be 95 percent confident that the actual S&A rate will be between **4.23** and **5.86** percent.

The graphs have been plotted over a reasonable range of estimated work placement for each District, since excessive extrapolation in either direction is risky. For example, New York District, which has been supervising an average of $30 to $40 million of work placement each year, would not be expected to perform in the same manner if it were suddenly tasked with supervising $150 million of work placement per year.

Table 2
Retrospective Test Results for FY76*

		1-Year-Ahead Prediction			2-Year-Ahead Prediction		
Division/District	Actual S&A Cost	Predicted S&A Cost	Lower Prediction Limit	Upper Prediction Limit	Predicted S&A Cost	Lower Prediction Limit	Upper Prediction Limit
Alaska	2.336	2.412	1.858	2.967	2.663	1.936	3.391
Baltimore	5.040	4.603	3.945	5.260	3.996	3.275	4.716
Fort Worth	4.947	4.930	4.098	5.761	4.932	4.010	5.853
Kansas City	1.721	1.797	1.583	2.011	1.822	1.610	2.034
Los Angeles	1.364	1.042	0.496	1.588	0.969	0.434	1.504
Mobile	4.357	4.671	3.957	5.385	3.922	3.102	4.741
New York	2.031	1.688	1.191	2.185	1.536	1.067	2.004
Norfolk	2.020	2.563	1.892	3.234	2.385	1.762	3.008
Omaha	7.202	10.099	7.844	12.355	8.808	6.887	10.729
Sacramento	3.259	3.699	3.105	4.293	3.519	2.910	4.129
Savannah	2.461	2.563	1.963	3.162	1.444	0.182	2.705

*Costs in millions of dollars.

5 MODEL USE AND MAINTENANCE

Model Use

The model can be used to predict the performance of a particular Division/District based on its past performance.

An estimated S&A cost for each Division/District can be calculated by substituting the estimated work placement, the appropriate time period (FY77 = 14, FY78 = 15, etc.), and the coefficients from Table 1 (FY65 through FY76 data) into the general prediction equation. The S&A rate is calculated by dividing the S&A cost by the estimated work placement and multiplying by 100. In Figures 1 through 11, the value of time is already accounted for and combined with the constant term. Similarly, the cross product term is combined with the estimated work placement term; therefore, only an estimated work placement is required. For example, Mobile District's prediction equation is:

$$S = 1.221 + .0432\,(W) - .117\,(T)$$

Assuming estimated work placement for FY77 at $100 million,

$$S = 1.221 + .0432\,(100)^{*} - .117\,(14)^{**}$$

Therefore,

$$S = \$3.90 \text{ million}$$

and

$$P = \frac{\$3.90}{\$100} \times 100 = 3.90 \text{ percent}$$

Based on this value of expected actual performance, the established limit may be set according to the current management policy for the District.

The S&A limits established by DMC may or may not be equal to the predicted rate. DMC could use the model to calculate the predicted S&A cost and the upper and lower 95 percent prediction limits for the estimated level of work placement. The values calculated could then be compared to the past S&A costs and the limit established at the value which seems most compatible with past S&A costs.

*100 is used because the model is based on millions of dollars.

**FY77 = 14.

Two examples using Table 2 and Appendix A will clarify the procedure. Consider the Omaha District S&A prediction for FY76. As reported in Chapter 4, Omaha District had an increase in work placement outside the range of model applicability in FY76. The FY76 values for predicted S&A cost and for lower and upper prediction limits for Omaha District are $10.099, $7.844, and $12.355 million, repsectively (from Table 2). These values are compared with the previous year's S&A cost, and, considering realistic lag times for increasing S&A capabilities, it appears that the most realistic limit is the lower prediction limit of 7.844 million dollars. This allows for a large (38.6 percent) increase in S&A cost without encouraging an unrealistic expansion of S&A.

New York District provides the second example. The estimated work placement for FY76 is $38.315 million. This represents a slight increase over FY75 work placement, but is still within the range of model applicability. The calculated values for predicted S&A cost, and lower and upper prediction limits are $1.688, $1.191, and $2.185 million, respectively (from Table 2). When compared with the S&A cost in FY75 of $1.924 million, it appears that the upper prediction limit is the most compatible limit. This is clear since the increase in work placement in FY76 implies that the S&A cost should increase slightly also. The only calculated value which represents an increase in S&A cost is the upper prediction limit.

In addition, since District performance is influenced by the established limit, DMC may predict the expected S&A rate and then establish the limit either below or above this value to restrict or expand the S&A effort, as desired. For example, if expansion is deemed necessary for a particular District based on past performance, the DMC may wish to establish the limit at the upper 95 percent prediction limit.

Using this procedure for improving the establishment of limits for all the Divisions/Districts for FY76 causes some significant changes. For three of the Districts (Norfolk, Omaha, and Sacramento), the established limit changes from the predicted S&A cost to the lower prediction limit. For two Districts (Baltimore and New York), the established limit changes to the upper prediction limit. This results in substantial improvement in the precision of the model predictions. The average deviation now is only 6.80 percent, with a range of 0.3 to 22.6 percent.

Model Maintenance

Changes in the model itself, the stability of model parameters, the "goodness" of fit of the model with the data, and the accuracy with which the model is predicting S&A costs should be checked periodically. Table 1 shows the changes in the model and the parameters as the model moved from year to year, beginning with the data from FY63 through FY74. Only four Districts retained the same model for all the years, while New York changed models every year. For most Districts, the coefficients for the parameters remained fairly stable. However, in some Districts, such as New York, a change in the model itself caused drastic changes in the parameter values, indicating that different model parameters may become significant as the model moves with time. Caution should therefore be exercised in predicting several years in advance.

When each year's data become available, the data base should be updated and the regressions performed for each District. Radical changes in the model used or in the parameter values should be noted. Similarly, decreasing values of R^2 and/or increasing values of S indicate that the model's predictive capabilities are decreasing.

Finally, the accuracy of the model as a predictor should be checked annually. Actual values which continually fall outside the prediction limits indicate basic inadequacies in the model itself.

6 CONCLUSIONS AND RECOMMENDATIONS

The model presented in this report provides a valid technique for estimating S&A costs as verified by the retrospective test. It is recommended that the DMC use this model as an aid in establishing S&A limits.

The results indicate that the unadjusted model predictions will have an average absolute deviation in the range of 10 to 15 percent. This deviation can be substantially reduced, by as much as half, by accounting for changes in expected district performance, conditions, and policy. Therefore, the DMC must consider changes in operating conditions or management policy within the District/Division when using the model in establishing S&A limits.

Although the model can be used to predict costs both 1 and 2 years in advance, the best results are obtained for predictions made 1 year ahead. Thus, the model should be updated with the past year's data before determining the new year's limits.

It is recommended that the model maintenance procedures described in Chapter 5 be implemented on DMC's computer system to provide DMC with the necessary technical capabilities to perform normal model maintenance.

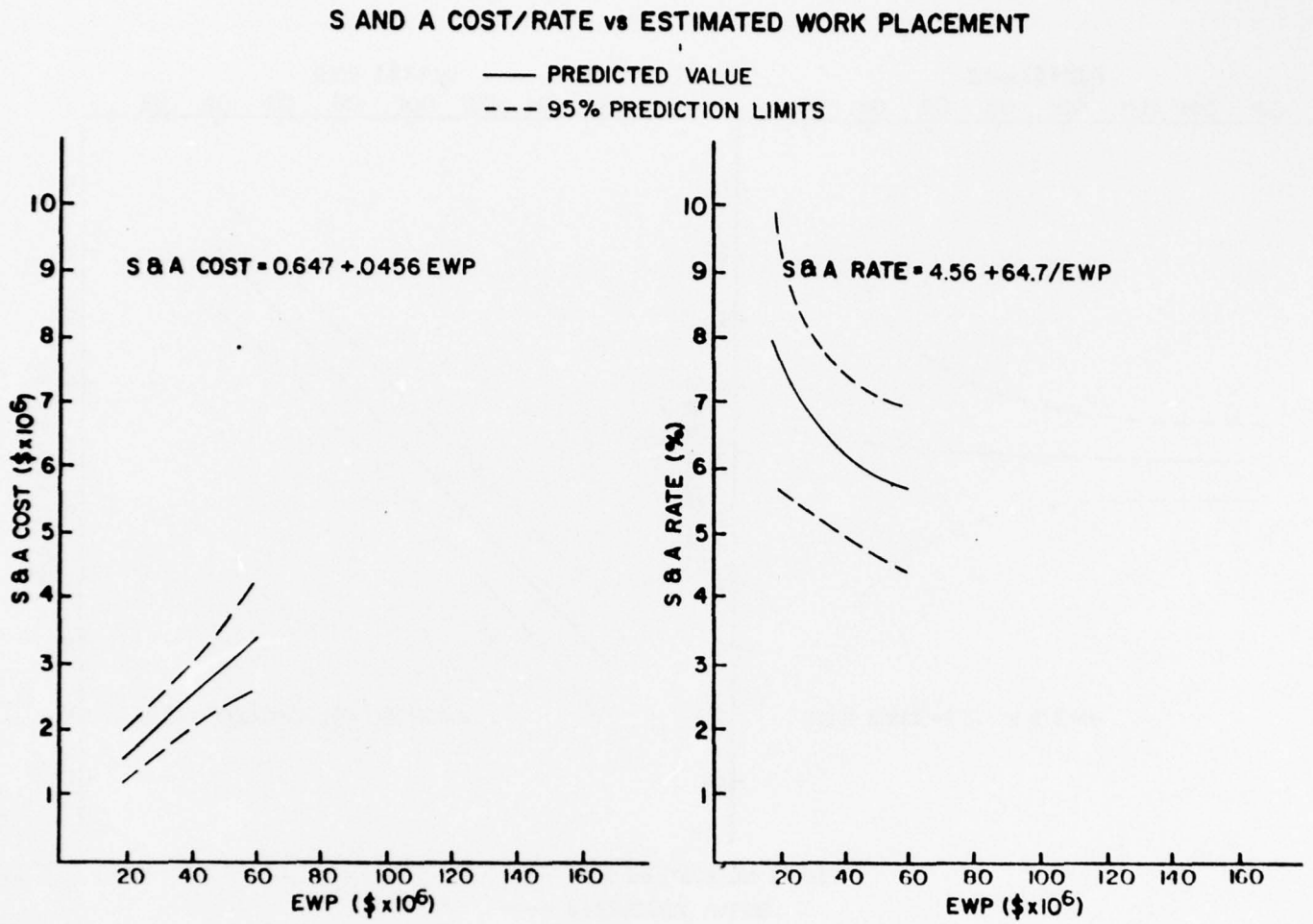

Figure 1. Predicted S&A costs/rates—Alaska District—FY77/FY78.

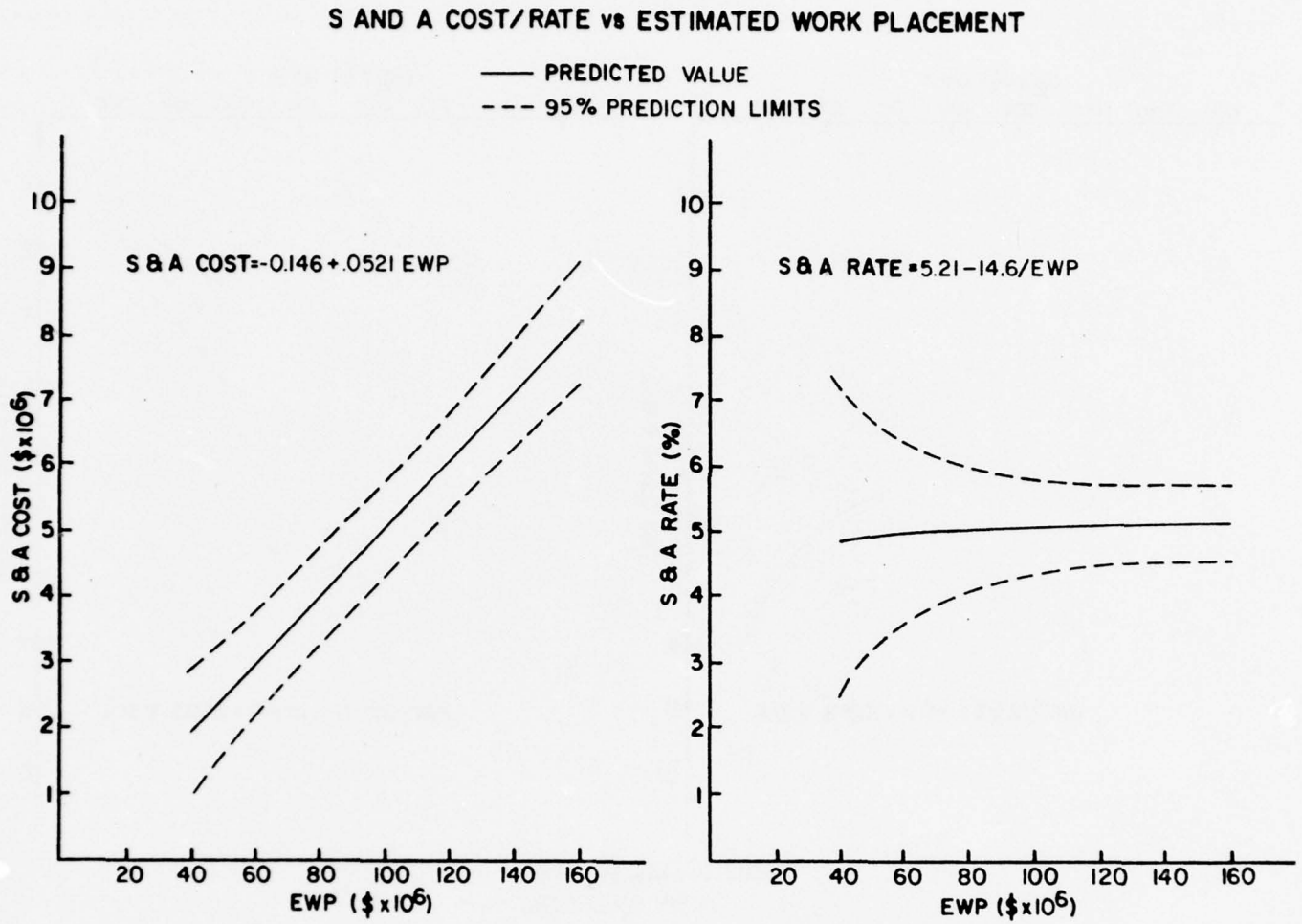

Figure 2a. Predicted S&A costs/rates–Baltimore District–FY77.

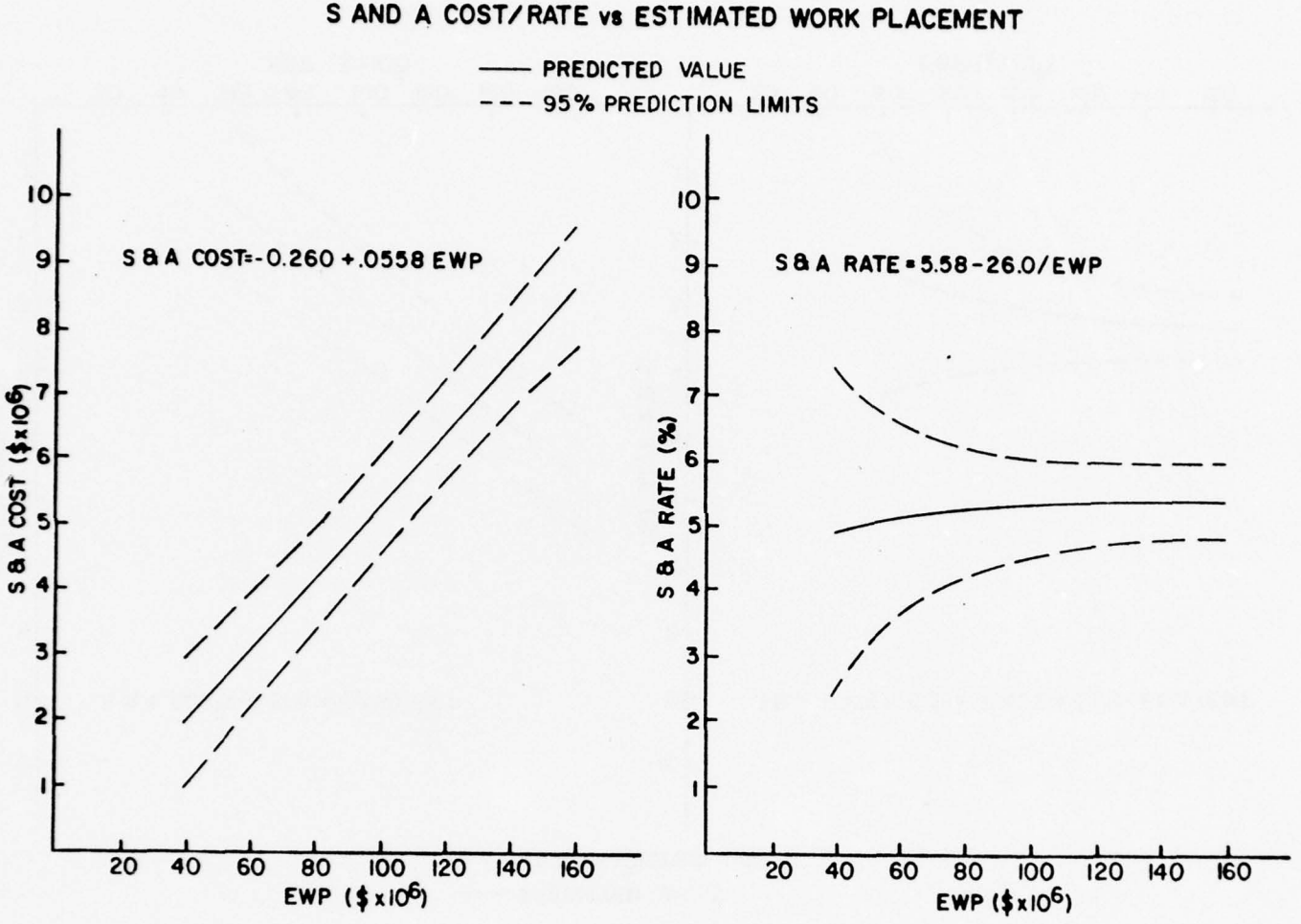

Figure 2b. Predicted S&A costs/rates—Baltimore District—FY78.

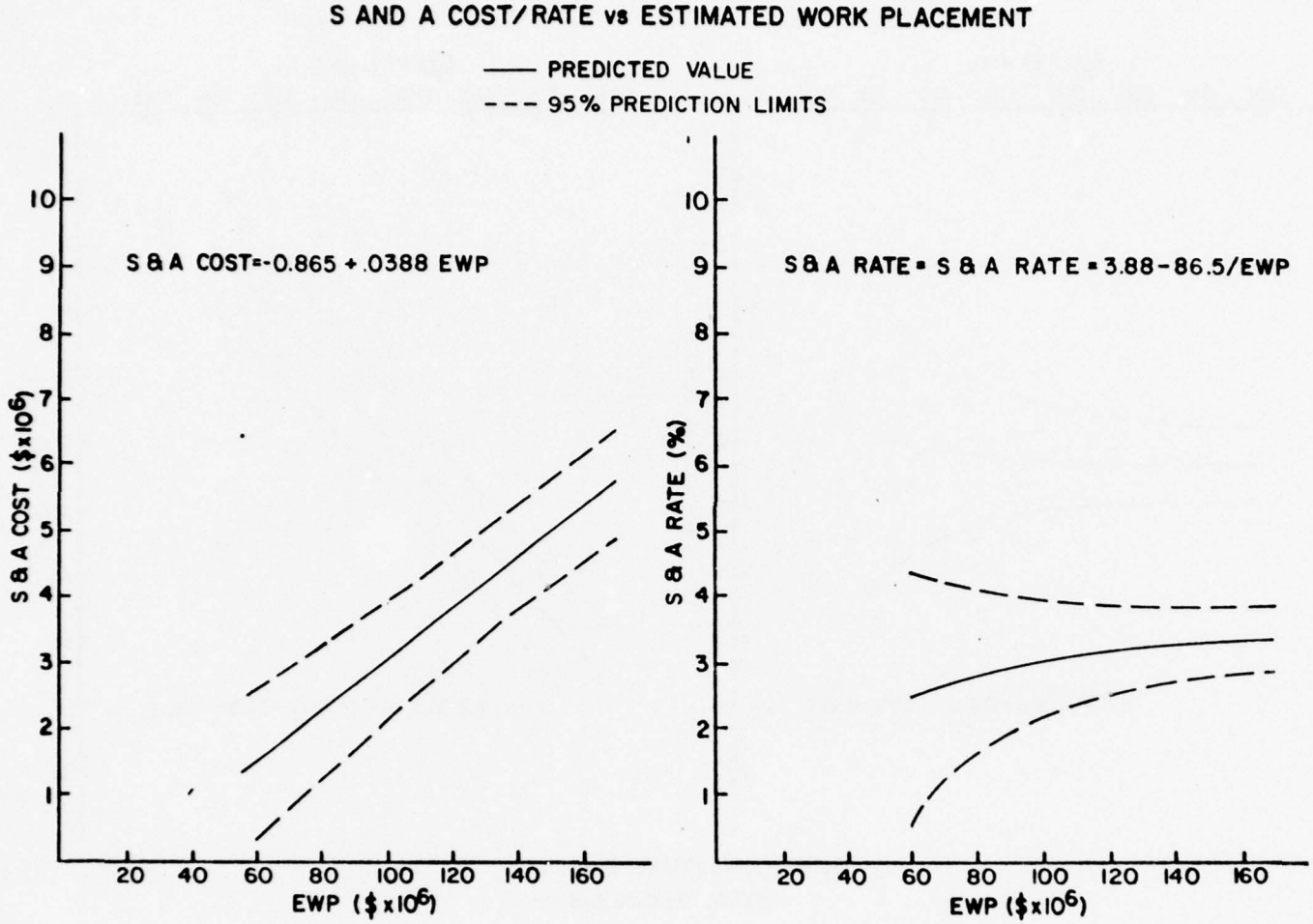

Figure 3a. Predicted S&A costs/rates—Fort Worth District—FY77.

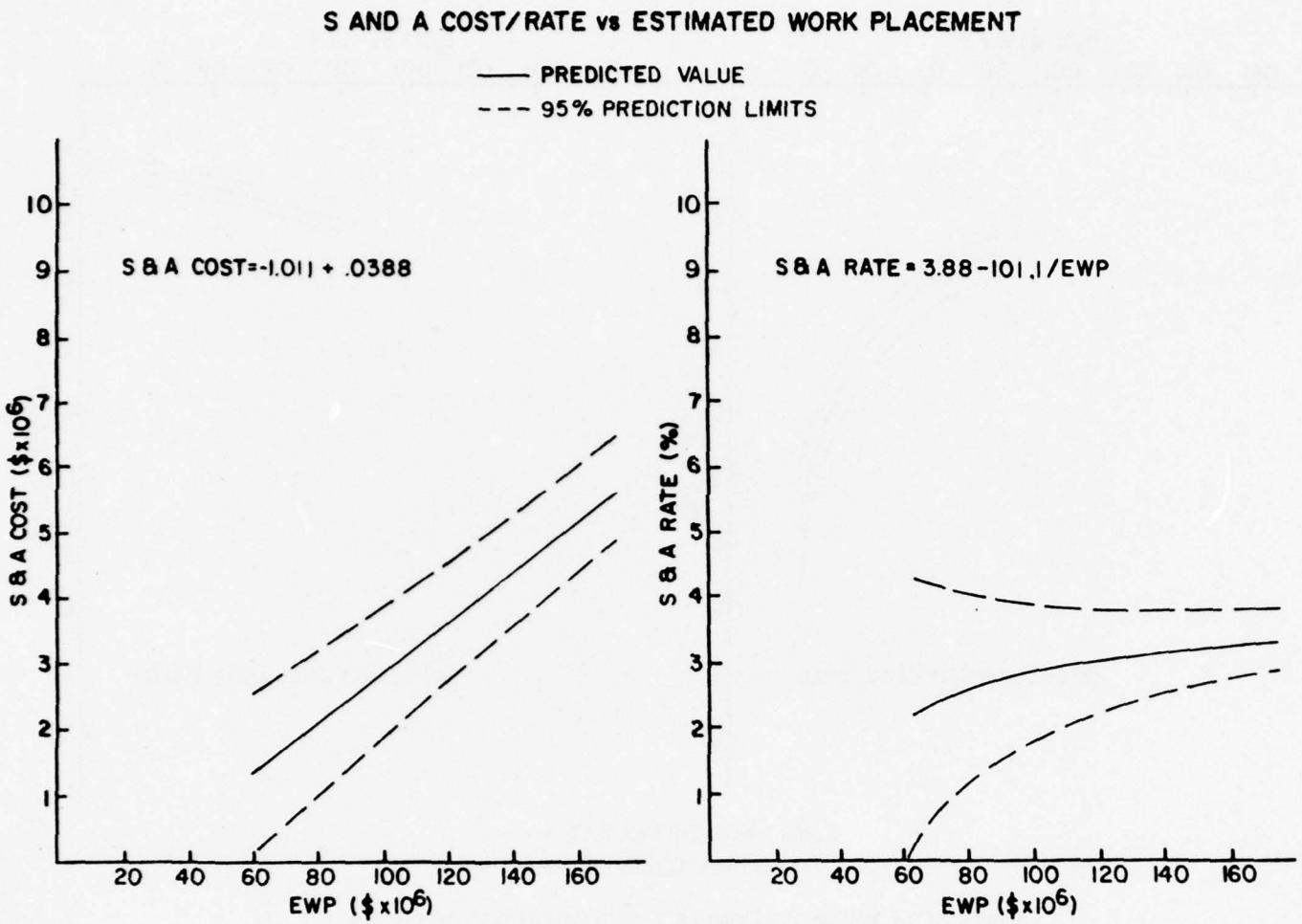

Figure 3b. Predicted S&A costs/rates–Fort Worth District–FY78.

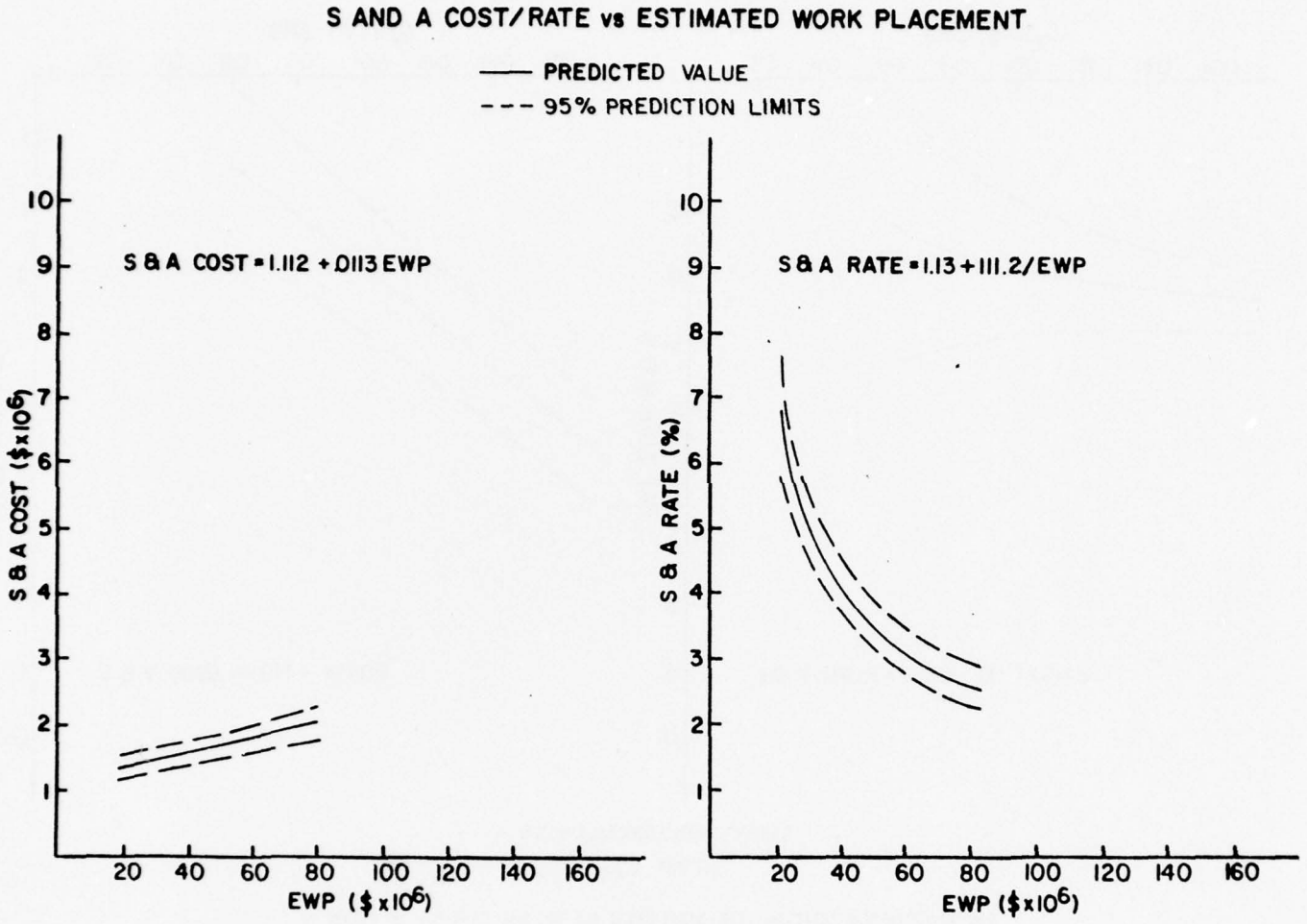

Figure 4. Predicted S&A costs/rates—Kansas City District—FY77-78.

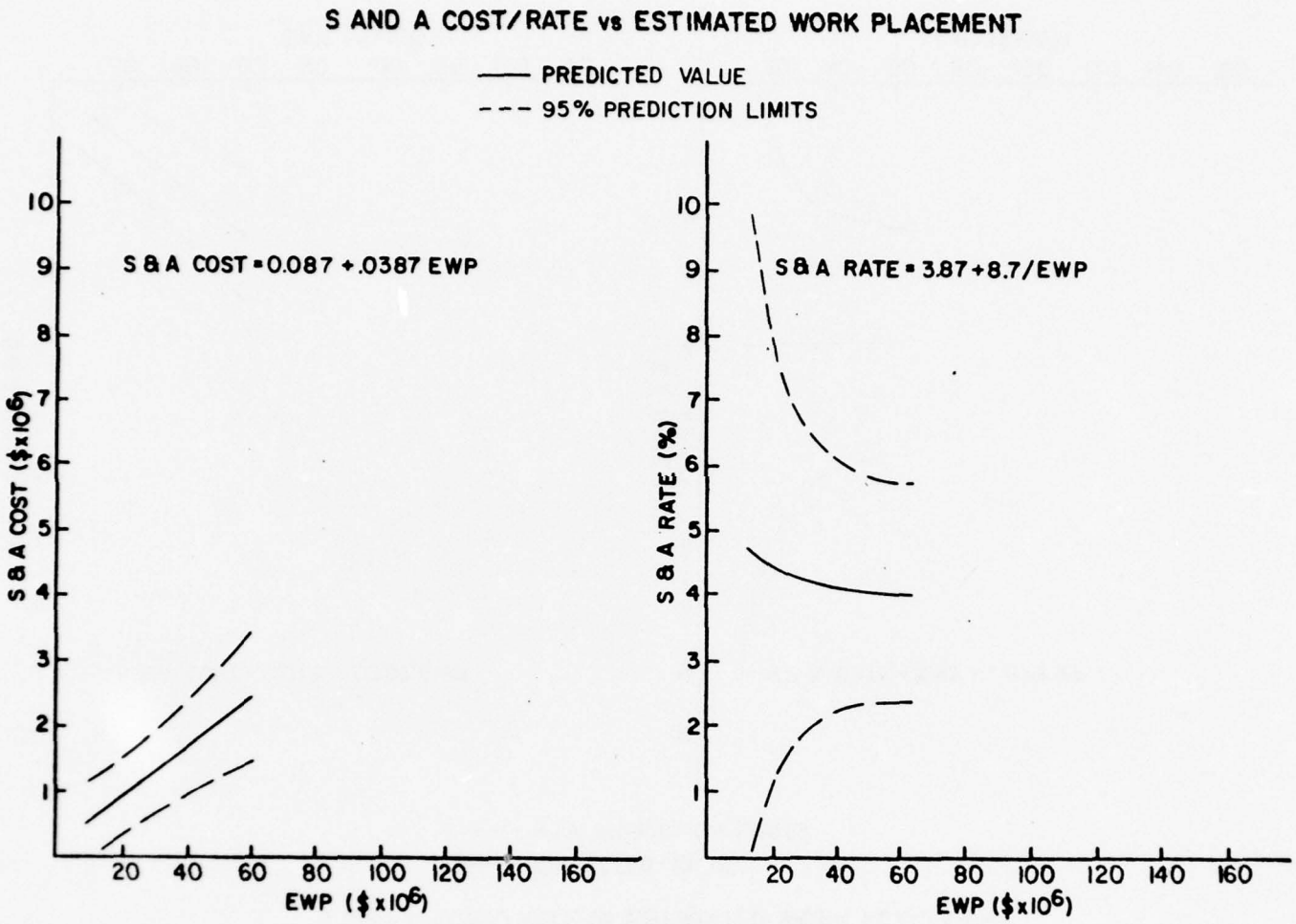

Figure 5a. Predicted S&A costs/rates—Los Angeles District—FY77.

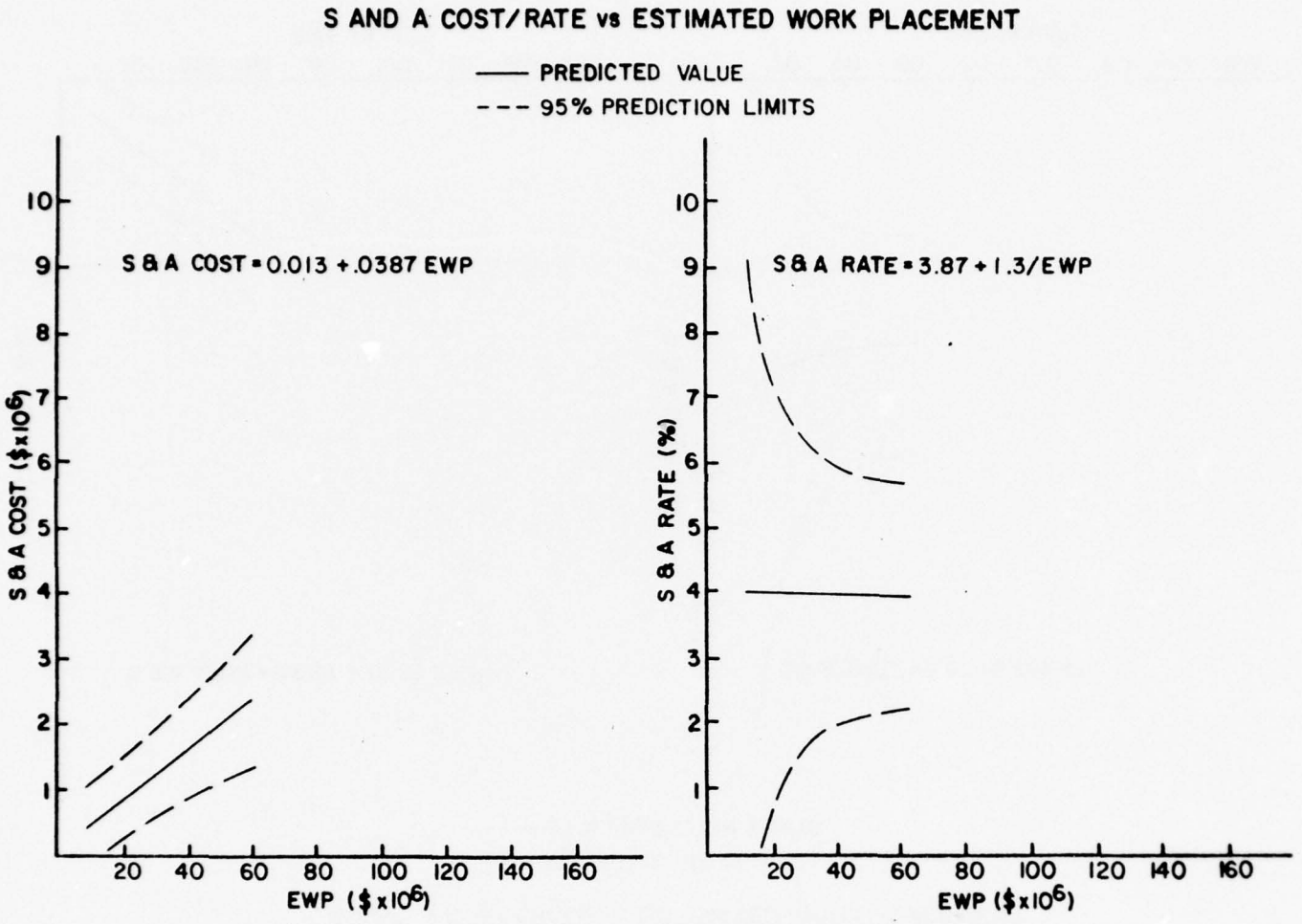

Figure 5b. Predicted S&A costs/rates—Los Angeles District—FY78.

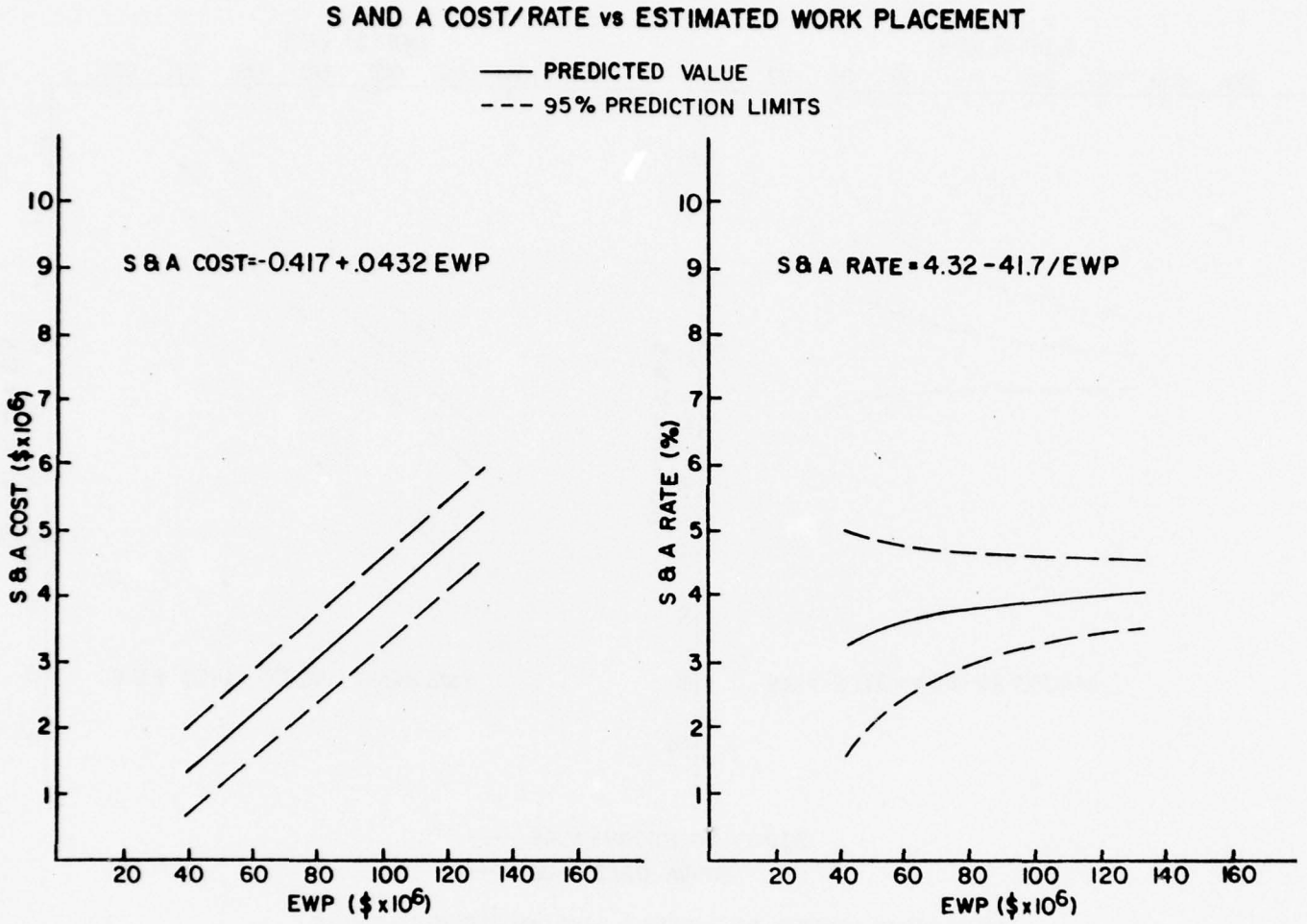

Figure 6a. Predicted S&A costs/rates–Mobile District–FY77.

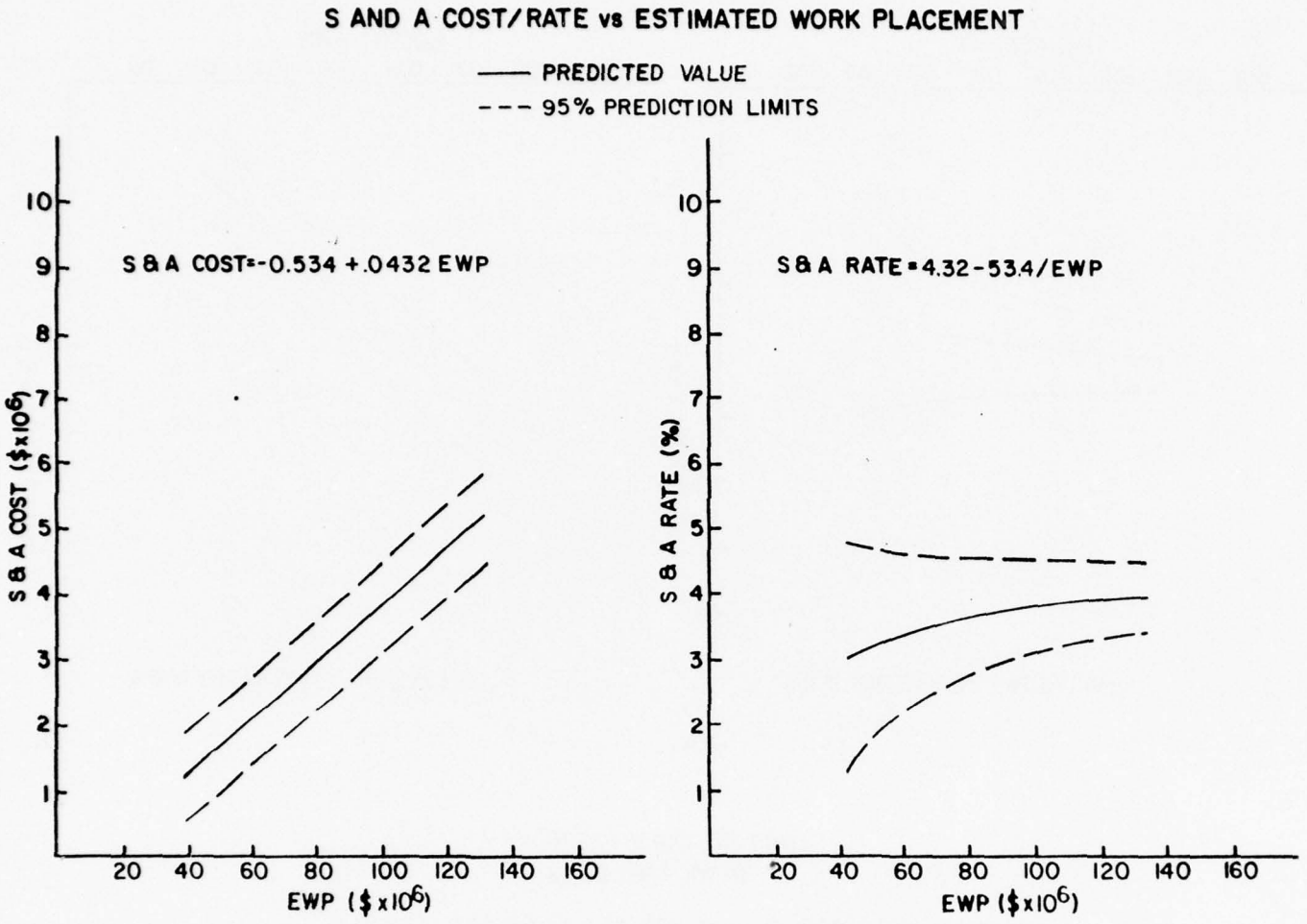

Figure 6b. Predicted S&A costs/rates—Mobile District—FY78.

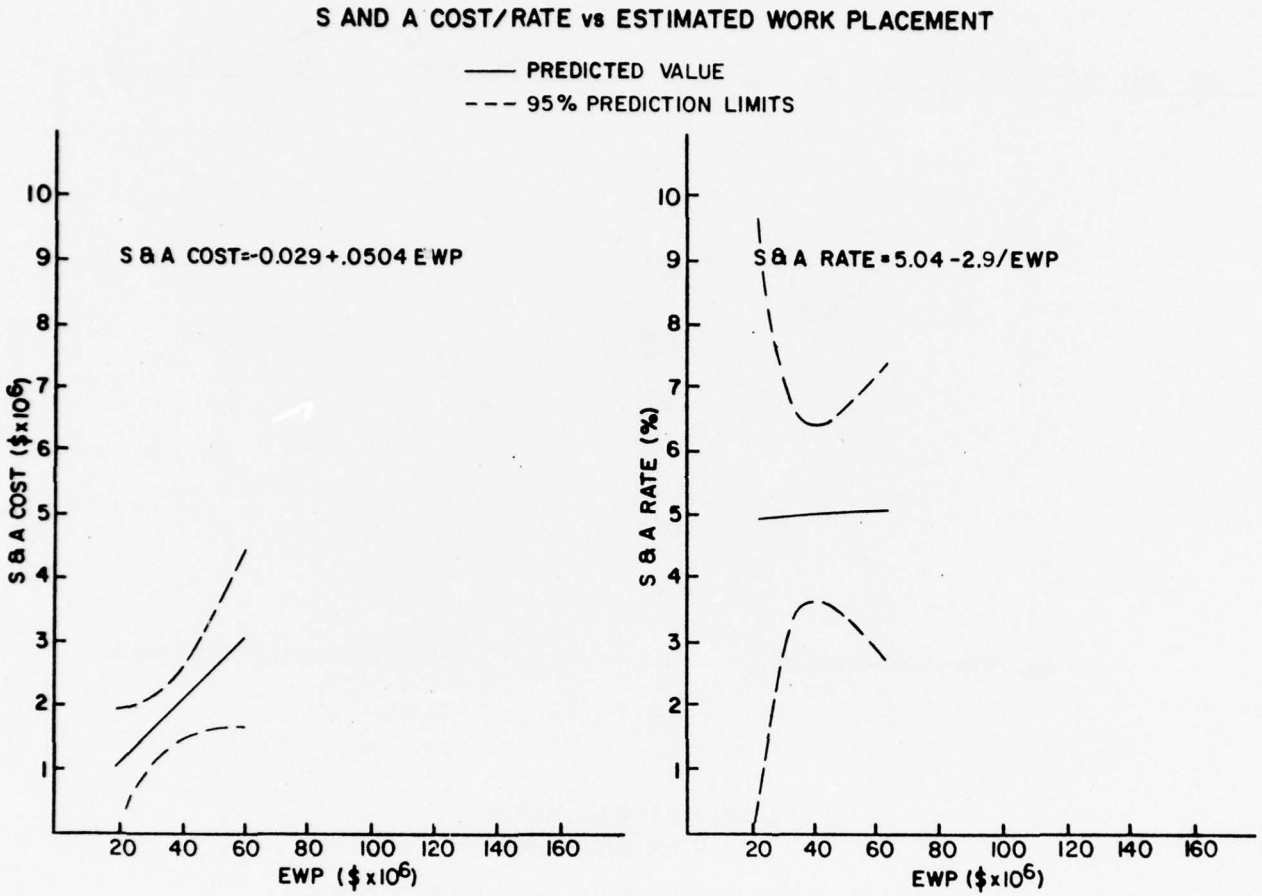

Figure 7a. Predicted S&A costs/rates–New York District–FY77.

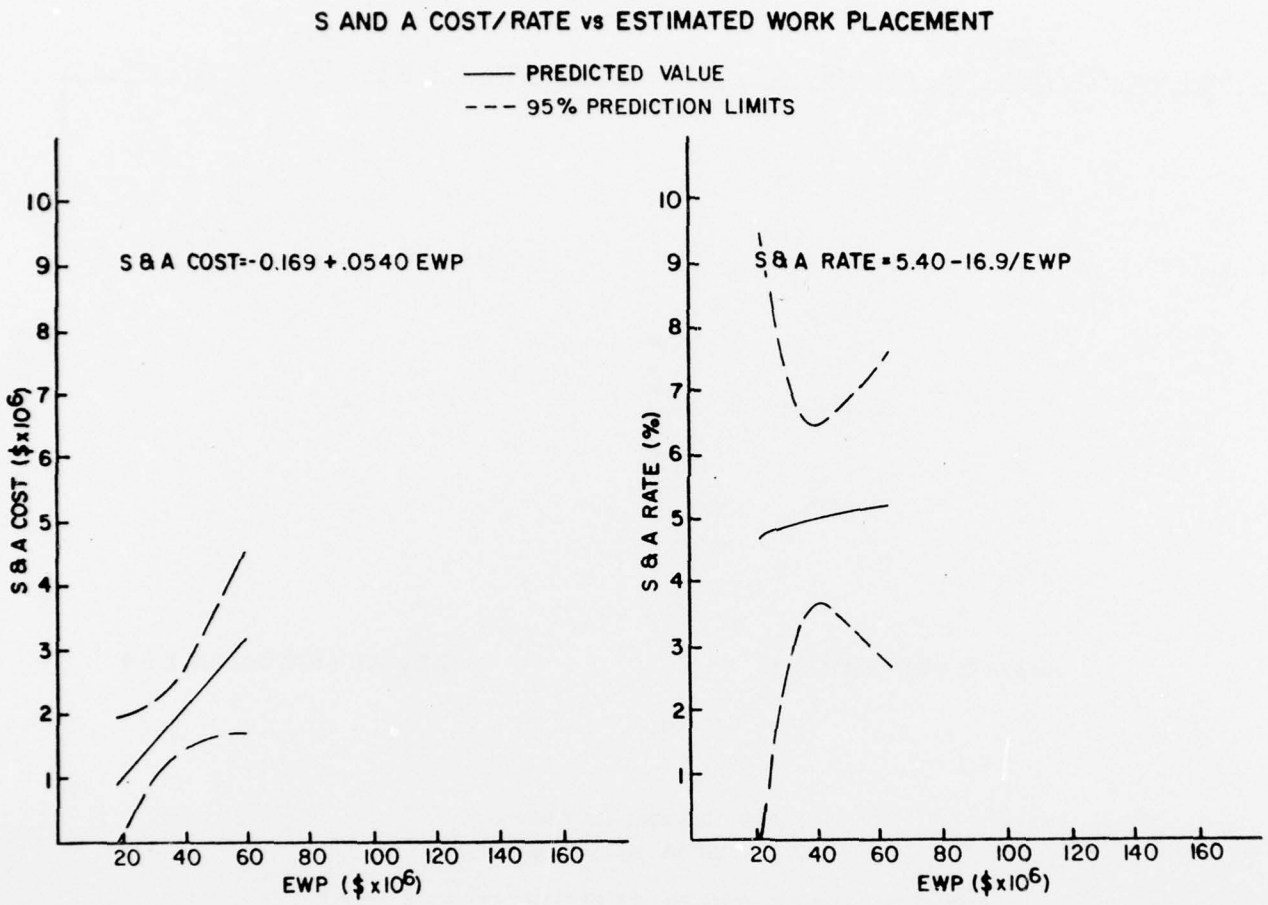

Figure 7b. Predicted S&A costs/rates—New York District—FY78.

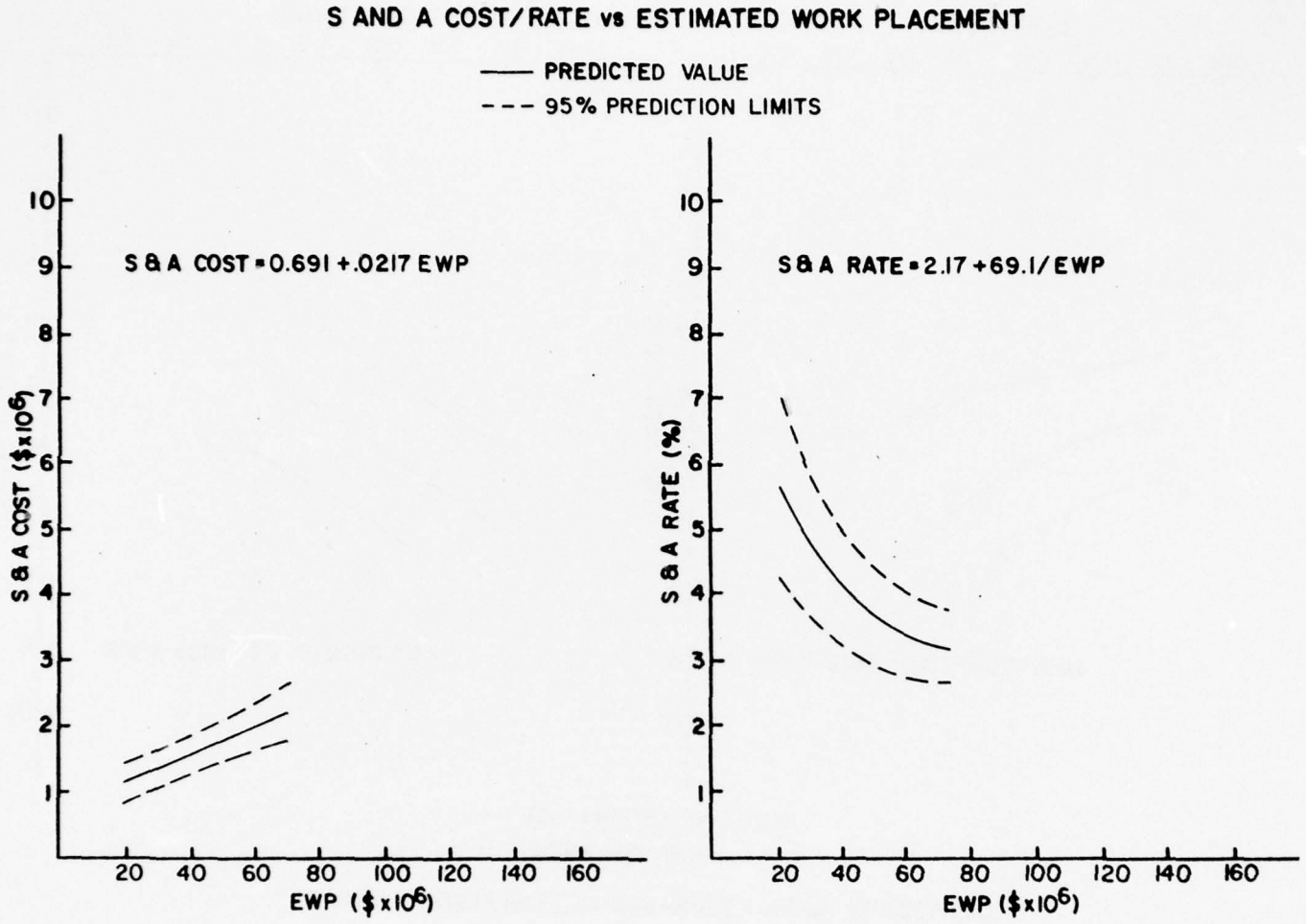

Figure 8. Predicted S&A costs/rates—Norfolk District—FY77/FY78.

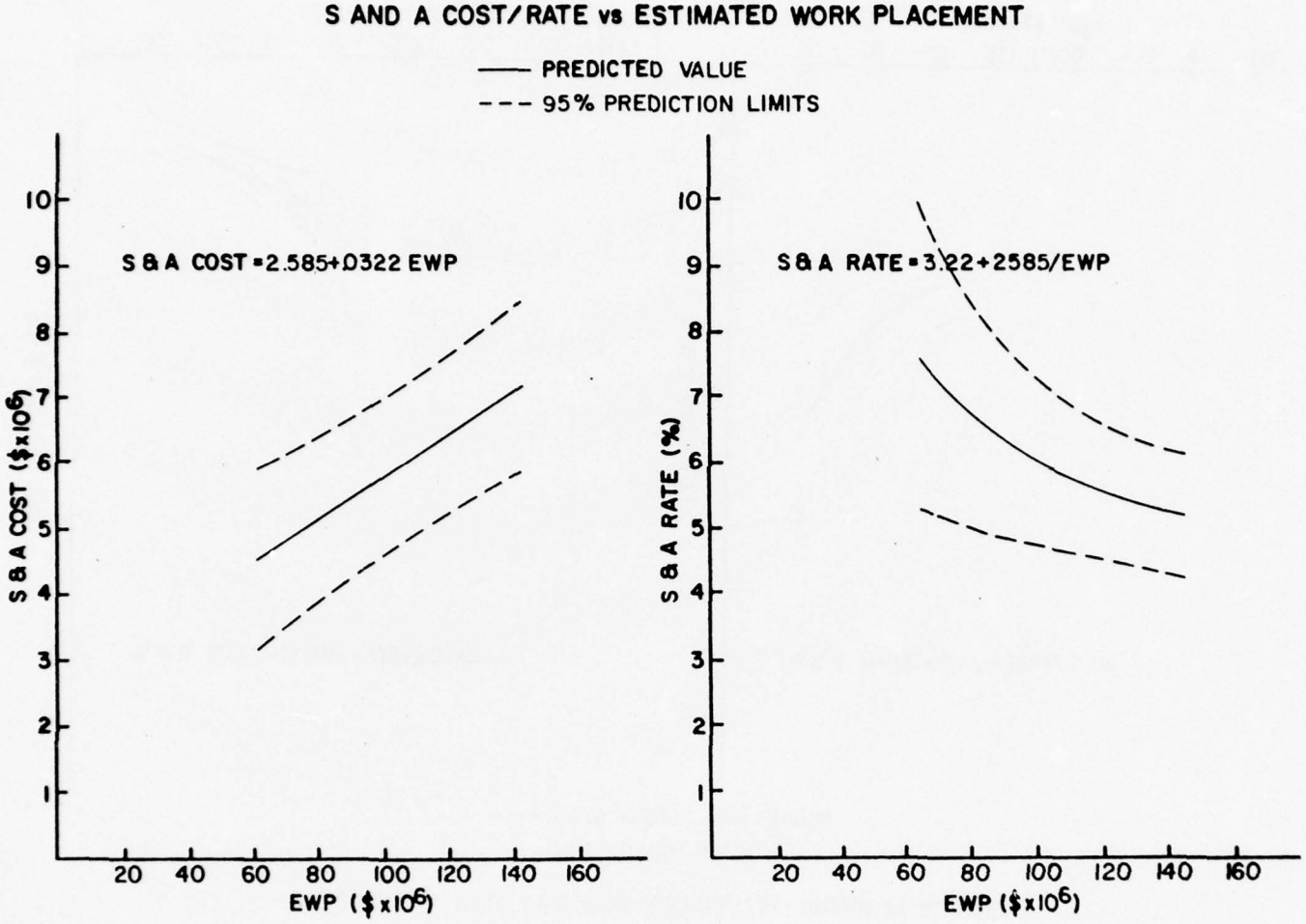

Figure 9a. Predicted S&A costs/rates—Omaha District—FY77.

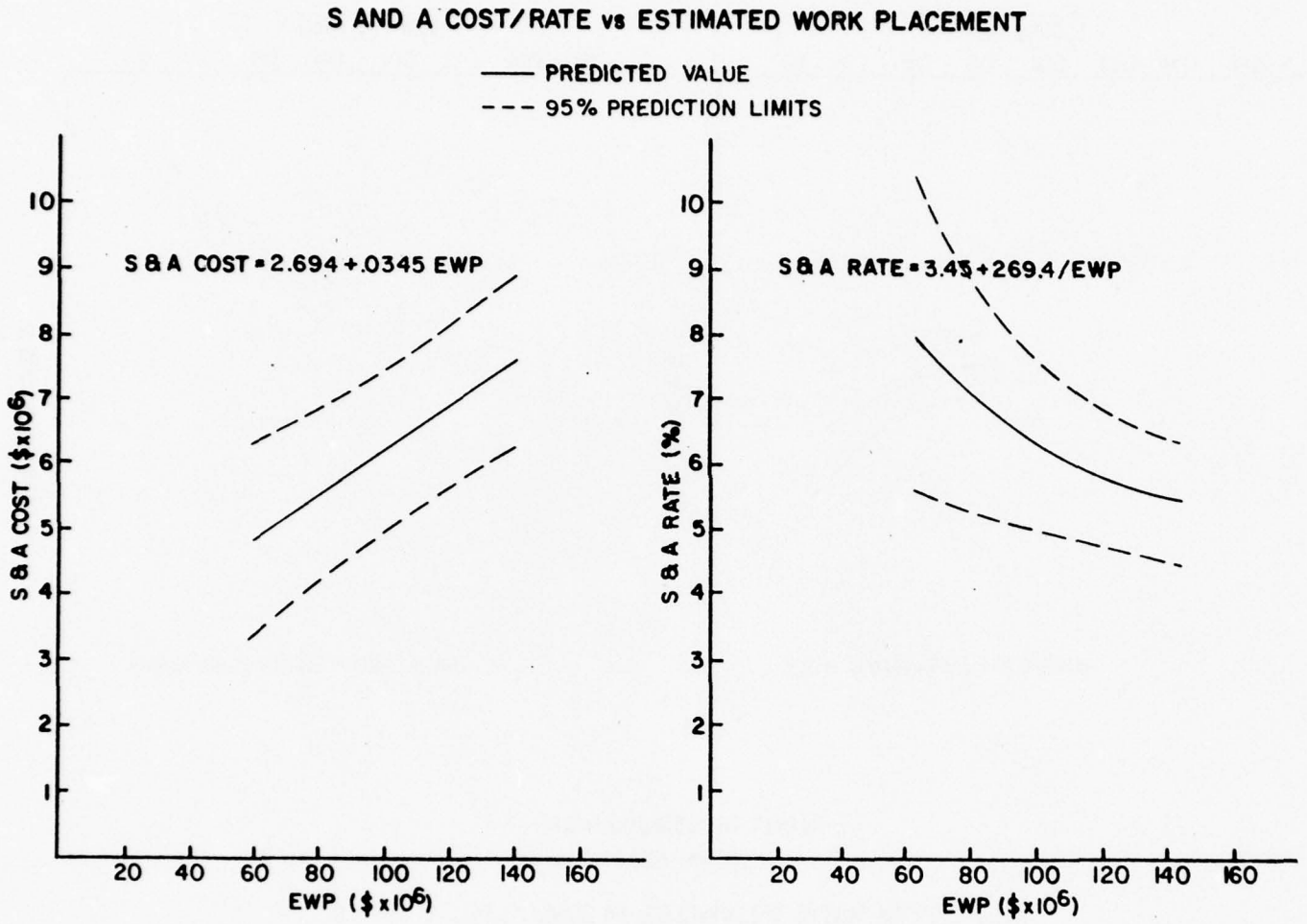

Figure 9b. Predicted S&A costs/rates—Omaha District—FY78.

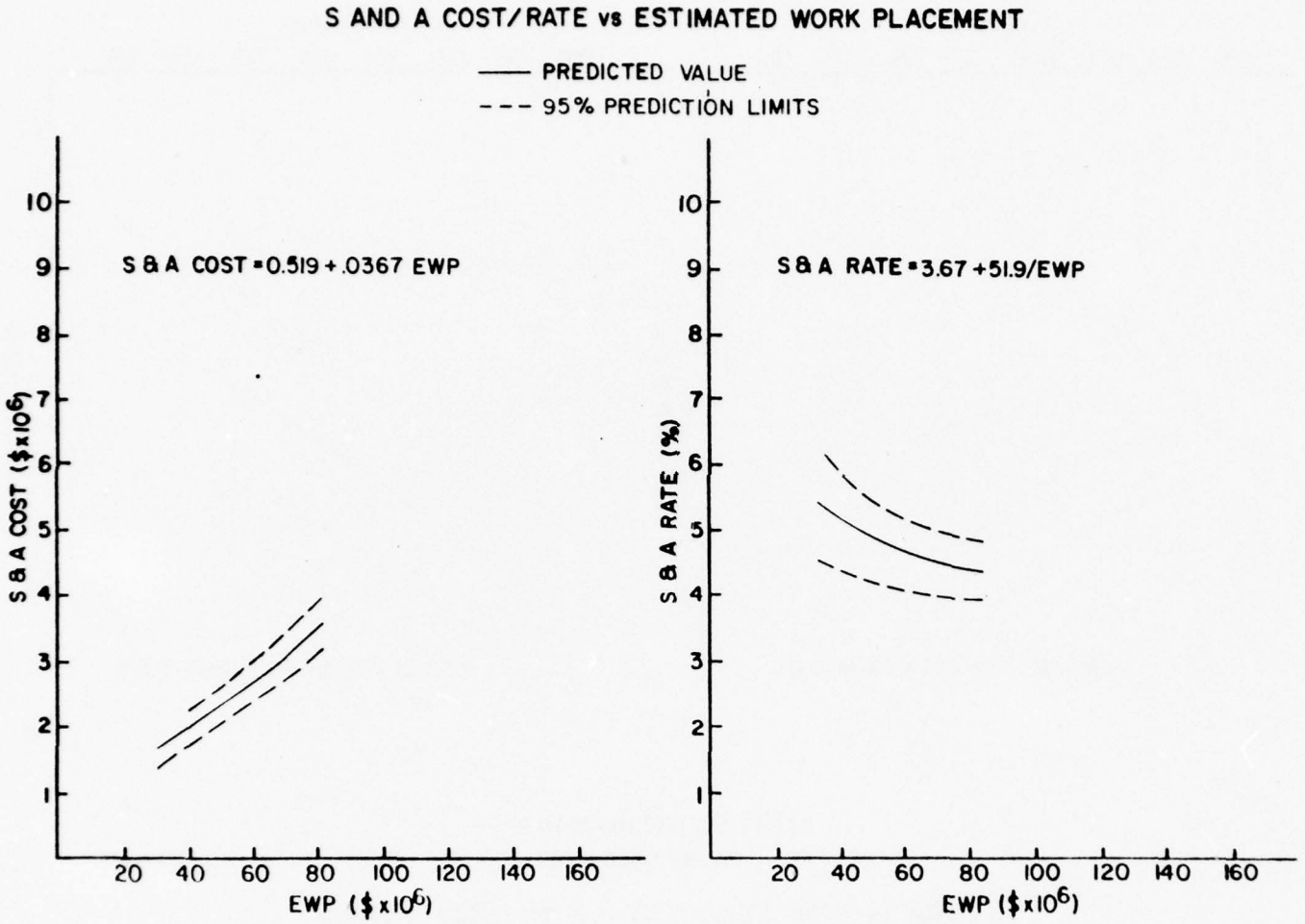

Figure 10. Predicted S&A costs/rates–Sacramento District–FY77/FY78.

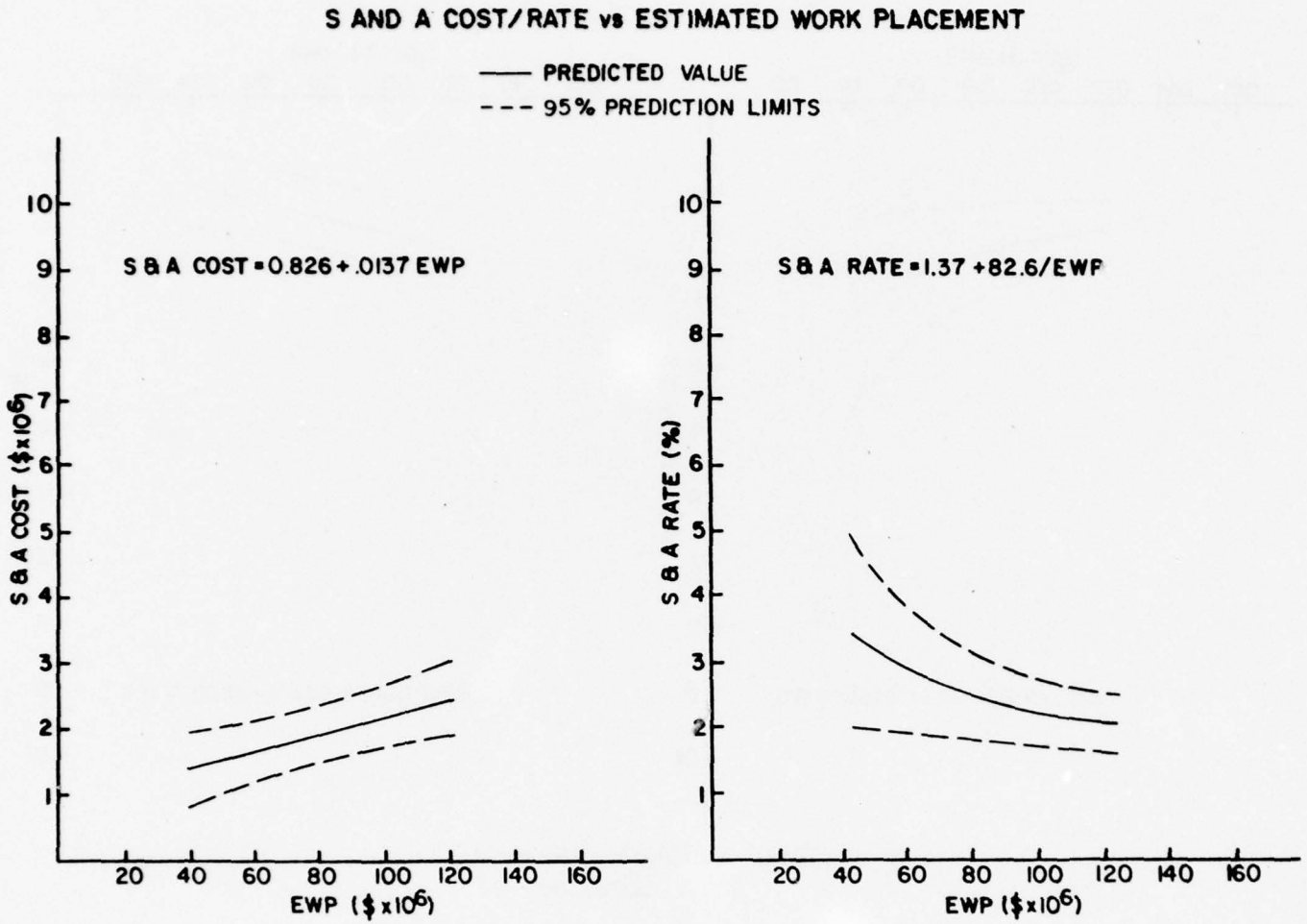

Figure 11a. Predicted S&A costs/rates—Savannah District—FY77.

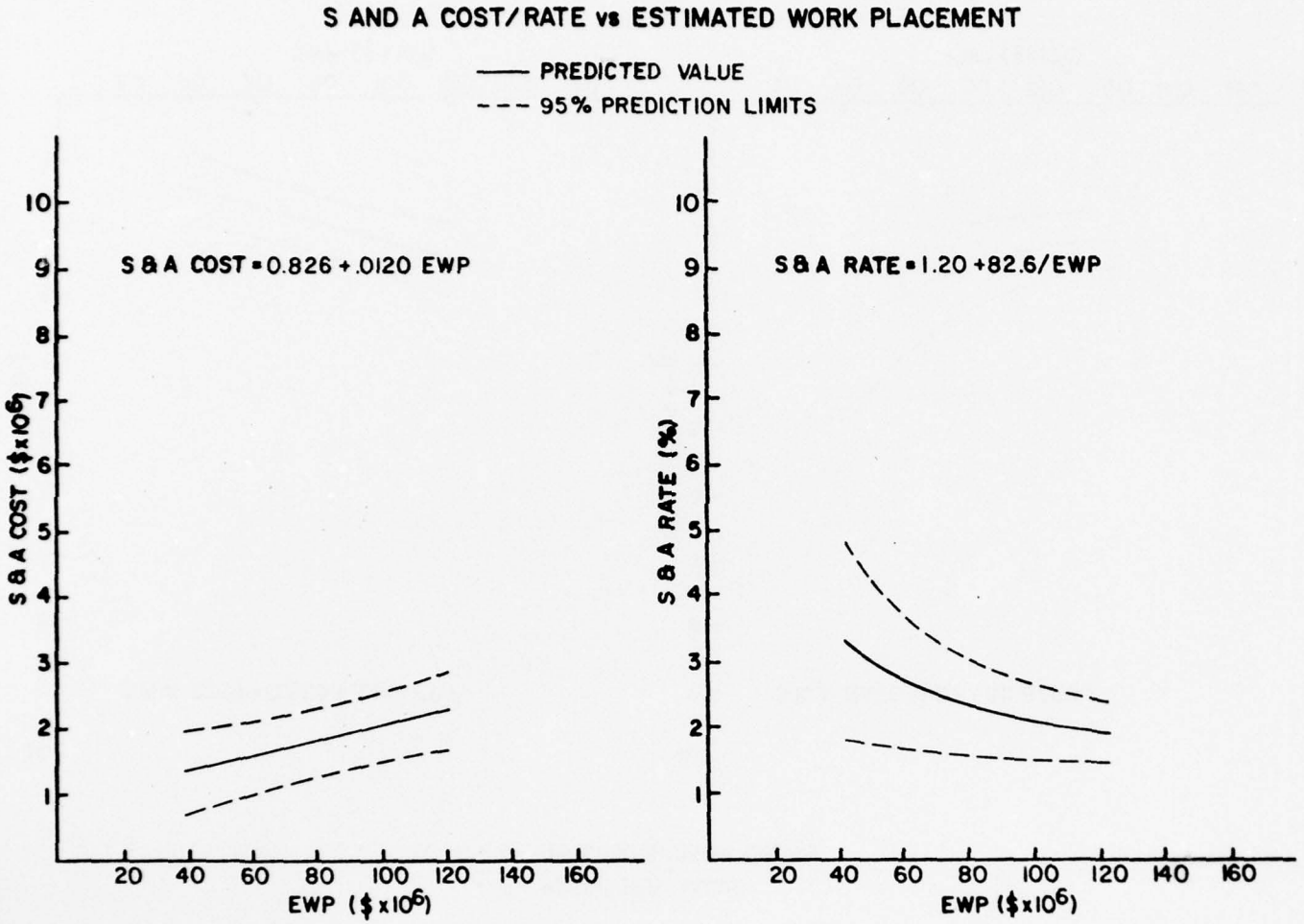

Figure 11b. Predicted S&A costs/rates—Savannah District—FY78.

APPENDIX A:

DIVISION/DISTRICT DATA FOR FY63 THROUGH FY76

Alaska District

FY	EWP (million $)	S&A Cost (million $)	S&A Rate (%)
1963	22.037	1.864	8.459
1964	25.116	1.632	6.498
1965	27.323	1.707	6.247
1966	20.477	1.701	8.307
1967	18.547	1.686	9.090
1968	21.731	1.636	7.528
1969	31.620	2.268	7.173
1970	27.356	1.794	6.558
1971	15.527	1.121	7.220
1972	18.567	1.458	7.853
1973	18.609	1.519	8.163
1974	29.411	1.789	6.083
1975	27.040	2.178	8.055
1976	38.287	2.336	6.101

Baltimore District

FY	Reported EWP (million $)	Reported S&A Cost (million $)	Adjusted EWP (million $)	Adjusted S&A Cost (million $)	Adjusted S&A Cost (%)
1963	21.865	1.527	21.865	1.527	6.984
1964	28.360	1.615	28.360	1.615	5.695
1965	23.911	1.590	23.911	1.590	6.650
1966	23.241	1.388	23.241	1.388	5.972
1967	24.150	1.459	24.150	1.459	6.041
1968	22.829	1.154	22.829	1.154	5.055
1969	20.134	1.153	20.134	1.153	5.727
1970	27.594	1.399	27.594	1.399	5.070
1971	60.197	2.523	37.028	1.322	3.570
1972	70.207	2.954	45.518	1.717	3.722
1973	87.406	4.309	61.197	3.041	4.969
1974	125.273	4.940	125.273	4.940	3.943
1975	136.329	6.191	136.329	6.191	4.541
1976	98.814	5.040	98.814	5.040	5.100

Fort Worth District

FY	EWP (million $)	S&A Cost (million $)	S&A Rate (%)
1963	48.133	2.799	5.815
1964	70.088	3.473	4.955
1965	60.789	3.353	5.516
1966	60.703	3.311	5.454
1967	33.835	1.958	5.787
1968	45.197	1.680	3.717
1969	47.883	1.823	3.807
1970	34.926	1.890	5.411
1971	67.368	2.861	4.247
1972	91.389	3.115	3.409
1973	102.148	3.914	3.832
1974	131.881	4.616	3.500
1975	144.427	5.035	3.486
1976	145.488	4.947	3.400

Huntsville Division

FY	EWP (million $)	S&A Cost (million $)	S&A Rate (%)
1969	3.008	1.057	35.140
1970	9.852	1.446	14.677
1971	108.452	5.844	5.389
1972	129.236	7.839	6.066
1973	76.335	5.279	6.916
1974	56.813	3.475	6.117
1975	33.860	2.005	5.921
1976			

Kansas City District

FY	Reported EWP (million $)	Reported S&A Cost (million $)	Adjusted EWP (million $)	Adjusted S&A Cost (million $)	Adjusted S&A Cost (%)
1963	26.928	1.389	26.928	1.389	5.158
1964	16.634	1.200	16.634	1.200	7.214
1965	20.554	1.469	20.554	1.469	7.147
1966	19.654	1.322	19.654	1.322	6.726
1967	16.600	1.214	16.600	1.214	7.313
1968	40.812	1.510	40.812	1.510	3.700
1969	44.792	1.633	44.792	1.633	3.646
1970	23.883	1.281	23.883	1.281	5.364
1971			35.725	1.605	4.493
1972			37.834	1.609	4.253
1973			39.944	1.603	4.013
1974			42.053	1.586	3.771
1975			44.163	1.559	3.530
1976	57.367	1.721	57.367	1.721	3.000

Los Angeles District

FY	EWP (million $)	S&A Cost (million $)	S&A Rate (&)
1963	51.538	3.038	5.895
1964	37.363	2.373	6.351
1965	43.393	2.398	5.526
1966	39.202	2.644	6.745
1967	35.116	2.428	6.914
1968	44.442	2.635	5.929
1969	54.555	2.742	5.026
1970	32.510	1.885	5.798
1971	32.226	1.511	4.689
1972	36.842	1.630	4.424
1973	19.769	1.022	5.170
1974	13.911	0.742	5.334
1975	26.849	1.402	5.222
1976	24.798	1.364	5.500

Mediterranean Division

FY	EWP (million $)	S&A Cost (million $)	S&A Rate (%)
1963	36.510	4.233	11.594
1964	29.119	3.393	11.652
1965	41.922	4.568	10.896
1966	50.030	4.114	8.223
1967	20.144	2.633	13.071
1968	16.982	2.552	15.028
1969	22.875	3.401	14.868
1970	45.844	4.599	10.032
1971	39.950	4.694	11.750
1972	52.174	3.158	6.053
1973	21.543	2.372	11.011
1974	20.404	2.728	13.370
1975	87.328	5.731	6.563
1976			

Mobile District

FY	EWP (million $)	S&A Cost (million $)	S&A Rate (%)
1963	42.640	2.496	5.854
1964	79.844	4.358	5.458
1965	106.752	5.461	5.116
1966	83.976	4.702	5.599
1967	56.270	3.395	6.033
1968	47.215	2.348	4.973
1969	24.827	1.636	6.590
1970	23.537	1.458	6.195
1971	39.222	2.001	5.102
1972	57.273	2.566	4.480
1973	66.972	2.731	4.078
1974	75.189	3.082	4.099
1975	87.188	4.041	4.635
1976	111.725	4.357	3.900

New York District

FY	EWP (million $)	S&A Cost (million $)	S&A Rate (%)
1963	18.415	1.105	6.001
1964	30.587	2.146	7.016
1965	29.911	1.942	6.493
1966	31.803	2.078	6.534
1967	29.590	1.828	6.178
1968	39.025	1.857	4.758
1969	27.286	1.551	5.684
1970	26.742	1.449	5.418
1971	42.173	1.995	4.731
1972	35.477	1.768	4.984
1973	33.186	1.711	5.156
1974	35.072	1.520	4.334
1975	31.210	1.924	6.165
1976	38.315	2.031	5.301

Norfolk District

FY	Reported EWP (million $)	Reported S&A Cost (million $)	Reported EWP (million $)	Reported S&A Cost (million $)	Reported S&A Rate (%)
1963	9.175	0.617	9.175	0.617	6.725
1964	8.028	0.550	8.028	0.550	6.851
1965	17.609	1.055	17.609	1.055	5.991
1966	15.382	1.055	15.382	1.055	6.859
1967	16.806	1.092	16.806	1.092	6.498
1968	24.459	1.246	24.459	1.246	5.094
1969	25.870	1.428	25.870	1.428	5.520
1970	15.713	1.039	15.713	1.039	6.612
1971			23.169	1.201	5.184
1972			24.689	1.237	5.010
1973			26.209	1.268	4.838
1974	21.852	0.818	21.852	0.818	3.743
1975	32.713	1.519	32.713	1.519	4.643
1976	63.125	2.020	63.125	2.020	3.200

Omaha District

FY	Reported EWP (million $)	Reported S&A Cost (million $)	Adjusted EWP (million $)	Adjusted S&A Cost (million $)	Adjusted S&A Rate (%)
1963	19.849	1.425	19.849	1.425	7.179
1964	23.628	1.618	23.628	1.618	6.848
1965	31.708	1.966	31.708	1.966	6.200
1966	25.397	1.897	25.397	1.897	7.469
1967	25.231	1.496	25.231	1.496	5.929
1968	30.910	1.490	30.910	1.490	4.820
1969	26.747	1.738	26.747	1.738	6.498
1970	32.541	2.311	32.541	2.311	7.102
1971	86.863	4.204	51.138	2.599	5.082
1972	118.817	5.359	80.983	3.750	4.631
1973	120.598	5.318	30.654	3.715	4.606
1974	115.667	5.830	73.614	4.244	5.765
1975	132.423	7.220	88.260	5.661	6.414
1976	167.489	7.202	167.489	7.202	4.300

Pacific Ocean Division

FY	EWP (million $)	S&A Cost (million $)	S&A Rate (%)
1963	31.466	3.103	9.861
1964	56.545	3.754	6.639
1965	58.109	4.347	7.481
1966	66.029	4.516	6.839
1967	109.511	6.752	6.166
1968	90.405	6.823	7.547
1969	84.958	6.667	7.847
1970	105.002	7.680	7.314
1971	49.834	4.034	8.095
1972	59.995	3.723	6.206
1973	47.900	2.653	5.539
1974	54.373	3.160	5.812
1975	65.915	3.847	5.836
1976	50.413	3.075	6.100

Sacramento District

FY	EWP (million $)	S&A Cost (million $)	S&A Rate (%)
1963	17.417	1.418	8.141
1964	29.892	1.976	6.610
1965	24.833	1.601	6.447
1966	25.703	1.489	5.793
1967	23.522	1.430	6.079
1968	18.609	1.107	5.949
1969	35.882	1.790	4.989
1970	32.021	1.651	5.156
1971	25.138	1.368	5.442
1972	38.419	1.688	4.394
1973	39.000	2.030	5.205
1974	44.560	2.248	5.045
1975	46.751	2.366	5.061
1976	75.782	3.259	4.300

Savannah District

FY	EWP (million $)	S&A Cost (million $)	S&A Rate (%)
1963	19.336	1.040	5.379
1964	19.401	1.257	6.479
1965	34.141	1.822	5.337
1966	53.730	2.454	4.567
1967	47.797	2.403	5.028
1968	52.253	2.320	4.440
1969	46.552	2.327	4.999
1970	45.927	2.151	4.684
1971	38.904	1.911	4.912
1972	45.216	1.660	3.671
1973	60.760	1.809	2.977
1974	66.755	2.021	3.027
1975	91.805	2.505	2.729
1976	107.018	2.461	2.300

APPENDIX B:

DATA ADJUSTMENTS

The Baltimore and Norfolk Districts were consolidated from FY71 through FY73, with the total work placement being reported by Baltimore. Both Baltimore and Norfolk District's data for these years were adjusted to reflect the amount of work that would have been placed by each District had they not been consolidated.

A simple linear relationship between work placement and time was formulated for Norfolk District, and work placement was estimated for FY71 through FY73, as shown in Figure B1a. A similar linear relationship between the S&A rate and year was developed (Figure B1b). The estimates of Norfolk District's work placement for FY71 through FY73 were multiplied by the respective estimated rates for these years to estimate the S&A costs shown in Figure B1c. The estimated work placement and S&A costs for Norfolk District were then subtracted from the reported work placement and S&A costs for Baltimore District. Figures B2a and B2b show these adjustments to Baltimore District data. Lastly, the adjusted S&A rates for Baltimore District were obtained by dividing the adjusted work placement for the affected years and multiplying by 100. Figure B2c shows these adjustments.

The Omaha and Kansas City Districts were consolidated from FY71 through FY75, with the total work placement being reported by Omaha. A similar procedure was used to adjust their data. Figures B3 and B4 show the results.

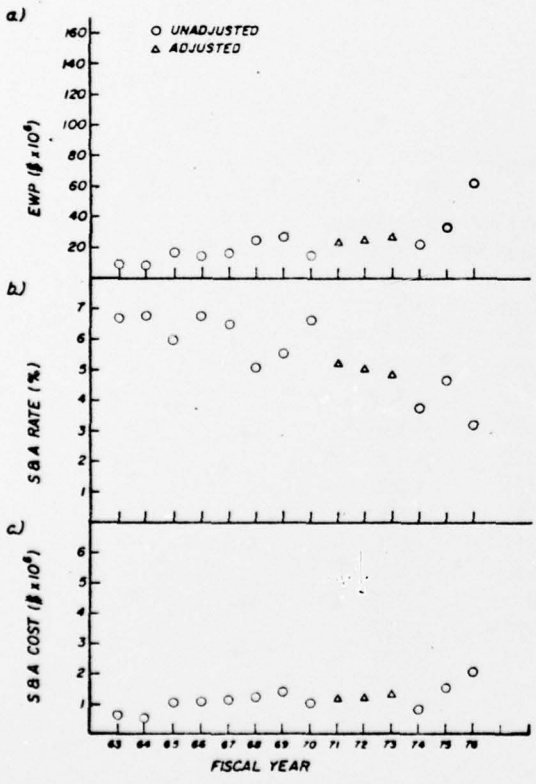

Figure B1. Norfolk District data adjustments.

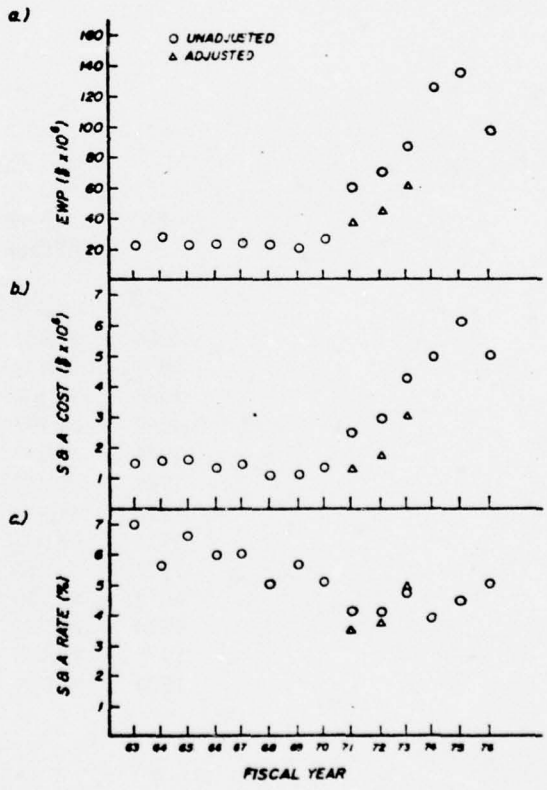

Figure B2. Baltimore District data adjustments.

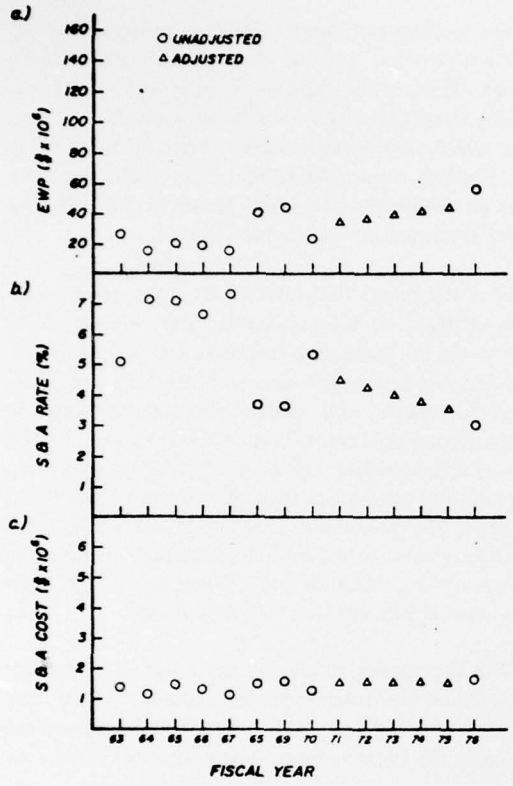

Figure B3. Kansas City District data adjustments.

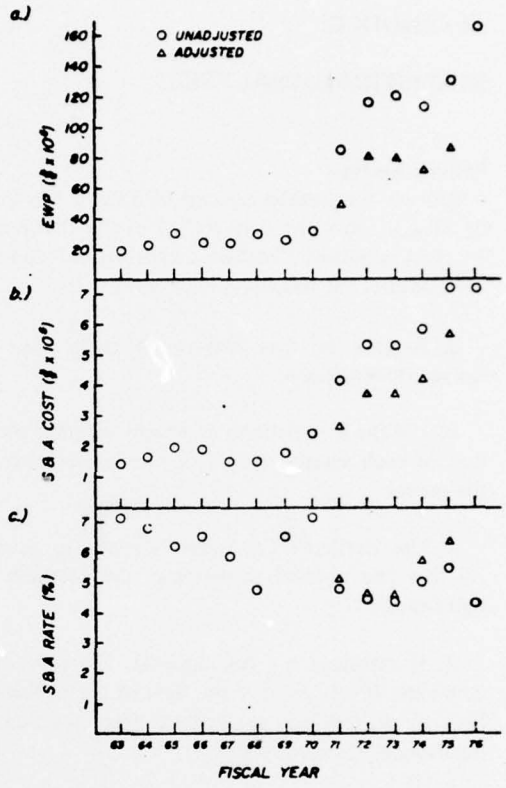

Figure B4. Omaha District data adjustments.

APPENDIX C:

STATISTICAL ANALYSES

Pooling Analysis

Due to the limited amount of data, it was initially decided to pool the data for all of the Divisions/Districts. A modified "backward elimination" approach[2] composed of the following steps was used:

a. Regress the data against the model with all of the variables included

b. Use the F statistic to determine whether the deletion of each variable would detract significantly from the model

c. Use Bartlett's Chi-Square statistic to determine whether the residual variances of the Districts differ significantly

d. If residuals are homogenous, the procedure is complete. If not, remove the data of the Division/District whose residuals are furthest from the mean residual variance and go to step a.

The Statistical Package for the Social Sciences (SPSS)[3] was used to perform the regression analysis. To accomplish the backward elimination, a dummy variable was used to indicate from which Division/District a particular data point came. Thus, the 12 Division/Districts had a total of 48 possible parameters, as shown in Eq C1.

$$S_i = b_{0i} + b_{1i}W_i + b_{2i}T + b_{3i}W_iT \quad \text{[Eq C1]}$$

$$i = 0, 1, \ldots, 11$$

The Bartlett Chi-Square test was then used to determine which Divisions/Districts had similar S&A cost behavior and should therefore be pooled. Table C1 shows the test results. Six Districts had to be removed before the data for the remaining six could be pooled. The same process was applied to determine if any of the six removed Districts could be pooled. It was found that each of these had to be treated separately.

Due to changes in performance or policy, the set of Divisions/Districts with similar behavior could easily change. Thus, after addition of each year's data, the pooling structure would have to be examined to determine which Divisions/Districts exhibited similar behavior. For this reason, the effect of not pooling any Districts on the six Districts which would be pooled in the model developed above was investigated.

Since the model that resulted from pooling the Districts included all the parameters, not pooling would only affect the prediction limits. In the pooled model, a pooled estimate of the variance was used while in the unpooled models, each District's variance was used in computing its prediction limits. The effect of not pooling was thus to tighten the prediction limits on the Districts with variances less than the pooled variance, and to widen the prediction limits on the Districts with variances greater than the pooled variance. Whether the change in the prediction limits was large enough to be considered significant was then determined.

With the pooling structures, there was an 18 percent chance that the Districts pooled actually did not have the same variance ($\alpha = .18$). If the Districts pooled did not have the same variance, using the pooled variance estimate would result in the prediction limits for the Districts with variances smaller than the pooled variance being wider than they should be and the prediction limits for the Districts with variances larger than the pooled variance being narrower than they should be.

For four of the Districts, the change in the prediction limits resulting from not pooling was less than 15 percent and was imperceptible when graphed. For Baltimore District and Mobile District, the limits increased approximately 25 percent. However, these Districts had large variances, and, due to the relatively large amount of α, it was decided that the increased limits described the level of confidence for these Districts better than the pooled limits.

Therefore, it was decided that pooling the Districts did not provide any significant improvement. Since the pooling did not significantly improve the prediction limits of the pooled Districts, and since the unpooled model is easier to maintain, it was decided not to pool any of the Divisions/Districts.

Number of Years Data Analysis

The initial mode developed was regressed against all of the data available on the assumption that the more

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[2]N. R. Draper and H. Smith, *Applied Regression Analysis* (John Wiley & Sons, Inc., 1966), p 167.

[3]Norman H. Nie, et. al., *SPSS—Statistical Package for the Social Sciences* (McGraw-Hill, 1975).

data used, the better the model would reflect the actual process. However, due to the increasing level of work placement, the earlier data may not reflect the current performance. If so, deleting the earlier data and using only a fixed number of the most recent years' data would make the model more sensitive to current changes in the Division/Districts' performances. If these changes represent a true change in performance, this increased sensitivity would be good. However, if these changes were just random fluctuations in the performance, then the model using more data would be less affected by these variations.

It was decided to investigate the effect of deleting some of the earlier years' data and basing the model on a fixed number of the most recent years' data. It was decided to use all of the available data in the model unless using fewer years' data resulted in significant reduction in the average percent absolute deviations. A minimum of 10 years of data was set as a lower limit for the amount of data necessary to get a significant regression. The test procedure consisted of comparing the actual S&A costs for FY76 with the predicted S&A costs using models based on data from:

a. FY63-FY75 (13 years) (all data available)

b. FY64-FY75 (12 years)

c. FY65-FY75 (11 years)

d. FY66-FY75 (10 years)

The procedure was as follows:

a. Use the backward elimination technique to determine the model reduction for each Division/District (no pooling)

Table C1
Homogeneity Test Results*

District	Step 1	Step 2	Step 3	Step 4	Step 5	Step 6	Step 7
Savannah	.042	.025	.025	.025	.025	.025	.025
Alaska	.029	.028	.028	.028	.028	.208	.028
Los Angeles	.035	.035	.035	.035	.035	.035	.035
New York	.042	.037	.037	.037	.037	.037	.037
Baltimore	.079	.046	.046	.046	.046	.046	.046
Mobile	.051	.049	.049	.049	.049	.049	.049
Fort Worth	.065	.065	.065	.065	.065	.065	
Sacramento	.017	.016	.016	.016	.016		
Norfolk	.035	.011	.011	.011			
Kansas City	.006	.005	.005				
Omaha	.156	.148					
Pacific Ocean	.232						
Probability** (α)	1.000	1.000	.999	.925	.671	.353	.178

*Entries are residual variances (millions of dollars^2)

**Probability, based on Bartlett's Chi-Square statistic, that there is a significant difference between the variances from District to District.

b. Calculate the percent absolute deviation between the predicted and actual S&A costs for each Division/District.

c. Use a paired t-test on the Divisions/Districts to determine if the percent absolute deviation was significantly reduced by using fewer years' data.

Table C2 shows the percent absolute deviations for FY76 for all the Divisions/Districts. Table C3 shows the comparisons between using all 13 years' data and using fewer years' data. Line 1 of the table shows the comparisons between using 12 years' data and using 13 years' data. The negative value for $\bar{D}$, the difference between the average percent absolute deviations, indicates an average improvement of 2.74 percent using 12 years' data instead of 13 years' data. The standard deviation of the differences for the Districts is given by S_D. The value of the t statistic, the degrees of freedom (df), and the associated value of α, the probability of rejecting a true hypothesis, are also shown.

The null hypothesis that the average percent absolute deviations between actual FY76 S&A costs and predicted FY76 S&A costs for models based on 13 and 12 years' data are equal can thus be rejected in favor of the alternative hypothesis that the average percent absolute deviations for the model based on 12 years' data is less than that for the model based on 13 years' data. This incurs a 5 percent risk of rejecting a true hypothesis. The null hypothesis that the model based on 12 years' data is as good as the models based on fewer years of data cannot be rejected without incurring unreasonably large risks.

The same analysis was applied to the FY75 data (Tables C4 and C5). Using less than 12 years of data did not result in a significant improvement. Hence, the null hypothesis that the model based on 12 years of data is as good as the models based on 11 or 10 years of data cannot be rejected.

In conclusion, the model based on 12 years of data provided significantly better predictions of FY76 S&A costs than the model based on 13 years of data; models based on 11 and 10 years of data did not provide further significant improvement for either FY76 or FY75. Hence, the most recent past 12 years of data should be used for model development.

Table C2
Percent Absolute Deviations Between Actual and Predicted S&A Costs for FY76

	Number of Years of Data			
District/Division	**13**	**12**	**11**	**10**
Alaska	3.4	3.3	4.5	7.6
Baltimore	8.5	8.7	8.4	7.5
Fort Worth	0.1	0.3	0.6	2.0
Kansas City	4.4	4.4	3.4	5.1
Los Angeles	22.6	23.6	26.6	28.5
Mobile	10.2	7.2	6.9	8.3
New York	27.1	16.7	16.5	20.2
Norfolk	30.5	26.9	14.5	35.6
Omaha	37.8	40.2	56.4	34.0
Sacramento	26.6	13.5	33.9	6.2
Savannah	7.9	4.1	0.8	26.8
Average	16.28	13.54	15.68	16.53

Table C3
Paired t-Test for FY76 S&A Costs
$H_o : \bar{D} = 0; H_1 : \bar{D} < 0$

Comparison	$\bar{D}$	S_D	t	df	α
12 vs 13 yrs	−2.74	4.900	−1.858	10	.05
11 vs 13 yrs	−0.60	9.184	−0.217	10	.42
10 vs 13 yrs	0.25	9.602	0.085	10	.53
11 vs 12 yrs	2.14	8.969	0.793	10	.78
10 vs 12 yrs	2.99	8.032	1.235	10	.88

Table C4
Percent Absolute Deviations Between Actual and Predicted S&A Costs for FY75

	Number of Years of Data		
	12	11	10
Alaska	15.6	14.8	15.0
Baltimore	14.0	13.6	13.6
Fort Worth	0.5	0.7	0.4
Kansas City	5.2	5.3	4.9
Los Angeles	19.0	20.5	25.4
Mobile	18.1	15.4	16.3
New York	29.3	31.5	30.2
Norfolk	10.4	11.8	8.0
Omaha	15.1	15.0	15.0
Sacramento	8.6	7.5	4.4
Savannah	30.1	27.5	13.8
Average	15.08	14.87	13.36

Table C5
Paired t-Test for FY75 S&A Costs
$H_o : \bar{D} = 0; H_1 : \bar{D} < 0$

Comparison	$\bar{D}$	S_D	t	df	α
11 vs. 12 yrs	−0.21	1.571	−0.441	10	.33
10 vs 12 yrs	−1.72	5.498	−1.037	10	.16

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